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TRANSMITTANCE MEASUREMENTS AT DIRT-II.(U)
JUL 80 J A CURCIO, K M HAUGHT, M A WOYTKO
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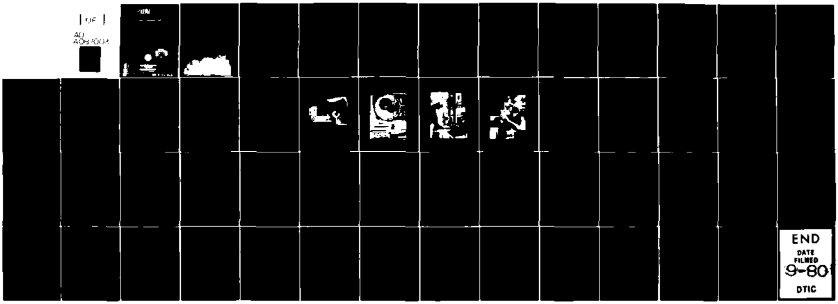

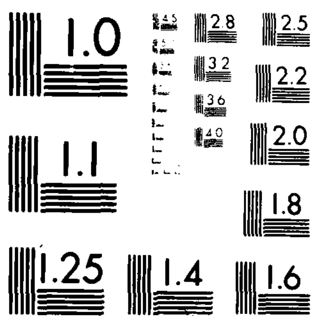

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The following change should be made:

The abstract in item 20 of the 1473 form (page i) should read July 1979, instead of July 1970.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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18. SUPPLEMENTARY NOTES

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Smoke spectral transmittance
Artillery smoke and dust
Battlefield smoke

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a report on the NRL experiments at the DIRT-II tests sponsored by the Atmospheric Sciences Laboratory at the White Sands Missile Range in July 1979. The NRL experiment was designed to measure spectral transmittance through smoke and dust clouds generated by detonations of various explosive charges and also by impact of artillery rounds. Spectral transmission data as a function of time for 0.55 μm, 1.06 μm, and 10.37 μm were

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20. (Abstract continued)

obtained for 63 events comprised of static detonations and artillery rounds. Transmission data for 1.06 µm, in most cases were similar and equal to 0.55 µm. In dry soil conditions the 10.37 µm channel showed higher transmittance values than the visible channel. There are indications that 10.37 µm transmittance in wet soil events is lower than visible presumably because strong liquid water absorption at the IR wavelength.

CONTENTS

BACKGROUND STATEMENT

Obscurants such as dust and smoke from artillery impacts and static detonations will cause serious degradation in the performance of electro-optical systems. The series of DIRT tests was designed to investigate various properties of smoke and dust which contribute to degradation of system performance. DIRT is an acronym for Dusty Infrared Transmission. DIRT-II was performed at White Sands Missile Range (WSMR) by the Atmospheric Science Laboratory (ASL) in conjunction with Explosion Effects Division, U. S. Army Engineers Waterways Experiment Station. One of the principal objectives of the tests was the determination of electro-optical transmission through dust and smoke clouds generated by static detonation and artillery rounds. These optical transmission tests were performed by the Naval Research Laboratory (NRL), sponsored by ASL, and conducted at three visible and infrared spectral regions discussed in this report.

TRANSMITTANCE MEASUREMENTS AT DIRT-II

I. INTRODUCTION

This is a final report on the NRL experiments at the DIRT II tests sponsored by the Atmospheric Sciences Laboratory at the White Sands Missile Range in July 1979. The NRL experiment was designed to measure spectral transmittance through smoke and dust clouds generated by static detonations of various explosive charges and also by impact of artillery rounds. Spectral transmission data as a function of time was obtained for 63 events comprised of static detonations and artillery rounds. No data were obtained for a few events because of wind conditions and equipment malfunction.

II. INSTRUMENTATION

The transmissometer used in the DIRT-II tests consisted of a source, receiver and associated recording and data processing equipment. A 600 watt halogen filled narrow filament tungsten lamp in a 24" diameter searchlight served as the source and had a bear width of 20 mr. Filament emission provided energy of 0.55 μm and 1.06 μm while the hot quartz envelop at 1000°C provided energy at 10.37 μm. Radiations were modulated at 750 Hz by a mechanically driven slotted chopper cage. Figure 1 shows the source assembly which was located 2 km from the receiver.

The receiver assembly consisted of a two-detector section for 0.55 μm and 1.06 μm and a coaxial section for 10.6 μm. The two-detector section consisted of 2 Si detectors, filter, beam splitter and lens; each detector had a FOV of 0.6 mr, equivalent to a field of about 60 cm diameter in the test area. A HgCdTe detector at the focus of a 60 cm diameter, f/2.5 mirror detected 10.37 μm radiation. The filter spectral half bandwidths were: 0.55 μm - 3.0 nm 1.06 μm - 0.01 μm and 10.37 μm - 0.15 μm. This section also had a FOV of 0.6 mr. Figure 2 shows the detector assembly and associated optics located in the receiver trailer. Leg supports resting on the ground decouple the receiver from all trailer motion.

The transmitter source was located at the south end of the optical path and pointed toward the receiver at the north end 2 km away. All live firing impacts and static detonations took place in a 200x300 meter area midway between transmitter and receiver sites and only rarely directly below the optical path. All data were

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obtained as the dust and smoke clouds moved through the optical beam about 10 m above ground.

The recording equipment was started at -3 min to determine the 100% and 0% transmission signal levels. Turnoff after the event occurred when the 100% level was re-established, for most events at about +2 minutes. Figure 3 shows receiver electronics and data recording equipment.

A visual telephotometer was used to monitor path attenuation during the test day. Figure 4 shows the telephotometer located in the receiver trailer. A large van, shown in Fig. 1, served as the visual target. Path visual extinction data is shown in Table 1.

A. Real-Time Acquisition of Transmissometer Data

The NRL transmissometer data were sampled and processed in real-time with a Hewlett-Packard model 9825A calculator. This calculator was configured with a HP model 98035A real-time clock and was interfaced to a digital voltmeter through an HP model 98033A BCD interface.

The calculator scanned the output voltage from each of the three transmissometer signal channels once each second. The voltage from each channel was processed to correct for that channel's 0%-transmission signal-level and its 100%-transmission level. Then the data for that one second interval were printed on paper tape and stored in the calculator's memory. At the conclusion of each DIRT-II event the stored transmission data were recorded on magnetic tape. Table II shows the relative location of each data-acquisition step within the overall DIRT-II fire-control countdown. Graphs of the resulting transmission data appear elsewhere in this report. We estimate the accuracy of the transmittance measurement to be about $\pm$ 5%.

B. Results and Discussion

Useful transmittance data were obtained on 63 events; 22 artillery shots and 41 static detonations. Table III lists a transmission data summary. Figure 5 thru Figure 69 are curves of transmission vs time for 0.55 μm, 1.06 μm and 10.37 μm for the 63 events. Tabular listings of spectral transmission vs. time were also developed but have not been included in this report. Transmission data for 1.06 μm in most cases was similar and equal to 0.55 μm. Since the transmitter beam was 10 m above ground at the test area, the dust cloud was sampled when it rose into the beam or was blown across. Dwell time in the beam varied from a few seconds to 2 minutes. In many cases a thin low cloud appeared about 1 sec after detonation. In most tests the beam was visually opaque when the cloud entered the beam, indicating a visual transmission of <.01%. Visual opaque level was determined by observing the searchlight source, in the 100% mode through calibrated neutral density filters. Useful data were obtained later, during the period when the cloud in the test volume was diffuse and the visual transmittance was > 1%. During this period the 10.37 μm channel showed higher transmittance values than the visible channel in more than 50% of the events. This is especially notable in events Arty A-1, Arty A-13, Arty B-7, A-11, B-7, E-4 and E-9 where 10.37 μm transmittances as much as 20% to 100% greater than 0.55 μm were observed. The higher ratio occurred at lower transmittance levels.

There are indications that IR transmittance of smoke and dust clouds in wet soil events is lower than visible transmittance presumably because strong liquid water absorption at the IR wavelength of 10.37 μm. For example, test C-2 in wet soil shows lower infrared transmittance in the first 13 seconds possibly because of moist soil particles present in the test volume. At +8 seconds transmittance was 10% visible vs 3% infrared. This effect was also observed for 7 seconds during test C-1 and for 19 seconds in test C-8. These effects were observed only on 26 July and 27 July after a strong rain storm on the evening of 25 July. At later times in a run when the moist particles have drifted or settled out of the test volume, the spectral transmission ratio is similar to that observed in dry soil tests. Based on bulk water attenuation coefficient of 785 cm^{-1} at 10.37 μm,[1] the increase in attenuation is attributed to liquid water in the moist soil. Definitive data would be obtained from measurements made in wet and dry soils at 3.0 μm where the liquid water bulk attenuation coefficient is 15x greater.

Examination of tabular data listings and curves of smoke and dust clouds generated in dry soils by static detonation and artillery impact seem to have similar spectral transmittance characteristics. In most cases IR shows higher transmission than visible during the same time period and cloud volume.

C. Conclusions and Recommendations

Through the light and diffuse regions of the clouds, IR at 10.37 μm showed greater transmittance than visible in about 50% of the events. Because of instrument limitations, no reliable data was obtained through the dark portions of the clouds. Modifications to the receiver system, for example parallel logarithmic channels, are needed to obtain data at low transmittance values through the dark clouds.

Turbulence fluctuations in the transmissometer beam above the hot desert floor introduced estimated uncertainties of ± 5% in the data. Test operation during period of quiet turbulence will reduce the noise.

Transmittance of the low lying diffuse cloud generated at detonation time is of particular interest because it will give data on soil dust uncontaminated by combustion products. This should be investigated at some future test.

Another feature that would seem to require further investigation is the spectral transmittance properties of clouds generated in wet soil conditions. This preliminary work shows IR suffering more attenuation than visible in wet soil conditions which is unlike dry soil conditions where IR shows higher transmission.

Acknowledgments

We wish to acknowledge gratefully the assistance and advice of Bruce Kennedy, Test Director of DIRT II and also Charles Gott of NRL for his assistance in the test preparations. We also wish to thank James Dowling for his critical review of the manuscript.

Reference

1. Irvine, W. M. and Pollack, J. B., "Infrared Optical Properties of Water and Ice Spheres," Icarus 8, 324-360 (1968).

Table I
DIRT-II Path Visual Extinction Data

Date	Time	(2 km) Transmission	Extinction Coefficient km^{-1}	Visibility km
July 17	1745	0.750	0.150	27.1
"	1845	0.810	0.110	37.1
July 18	1445	0.750	0.150	27.1
"	1700	0.850	0.080	47.7
"	1750	0.905	0.050	78.6
"	2000	0.873	0.068	57.6
July 19	1455	0.800	0.112	34.9
"	1530	0.870	0.072	54.5
"	1635	0.850	0.074	53.3
"	1655	0.860	0.075	53.0
"	1810	0.875	0.066	59.4
"	1840	0.920	0.045	88.0
July 20	1455	0.790	0.115	34.0
"	1545	0.810	0.103	38.0
"	1630	0.830	0.096	41.0
"	1725	0.820	0.098	40.0
"	1805	0.820	0.098	40.0
"	1835	0.880	0.061	64.0
July 21	1415	0.820	0.101	38.7
"	1445	0.750	0.143	27.5
"	1620	0.800	0.111	35.2
"	1645	0.791	0.117	33.5
"	1710	0.878	0.065	60.4
"	1820	0.871	0.069	56.9
July 23	1410	0.770	0.128	30.5
"	1450	0.785	0.121	32.4
"	1530	0.763	0.135	29.0
"	1610	0.798	0.113	34.8
"	1700	0.805	0.108	36.2
"	1725	0.826	0.096	41.0
July 24	1425	0.802	0.111	35.5
"	1455	0.805	0.108	36.2
"	1545	0.864	0.073	53.4
"	1610	0.826	0.096	41.0
"	1640	0.830	0.093	42.2
"	1710	0.835	0.090	43.5
"	1735	0.844	0.085	46.2
July 25	1420	0.646	0.219	17.9
"	1450	0.787	0.120	32.7
"	1540	0.769	0.131	29.9
"	1620	0.800	0.111	35.2
"	1655	0.835	0.090	43.5

Table I (Continued)
DIRT-II Path Visual Extinction Data

Date	Time	(2 km) Transmission	Extinction Coefficient km^{-1}	Visibility km
July 25	1730	0.797	0.116	33.9
"	1805	0.838	0.088	44.4
July 26	1445	0.750	0.144	27.3
"	1515	0.795	0.115	34.2
"	1540	0.810	0.105	37.2
"	1600	0.825	0.096	40.9
"	1625	0.839	0.088	44.5
"	1700	0.845	0.084	46.5
"	1735	0.854	0.079	49.7
July 27	1400	0.832	0.092	42.6
"	1450	0.812	0.104	37.6
"	1535	0.801	0.111	35.3
July 28	1410	0.766	0.134	29.4
"	1500	0.777	0.126	31.1
"	1600	0.804	0.109	36.0
"	1630	0.844	0.085	46.4
"	1705	0.845	0.084	46.5
"	1745	0.837	0.088	44.1

TABLE II
NRL Transmissometer Data-Acquisition Sequence

Fire-Control Count	Data-Acquisition Step
- 180 sec	0%-TRANSMISSION MODE Block detectors Sample 0% level for 30 sec
- 120 sec	100%-TRANSMISSION MODE Unblock detectors Sample 100% level for 30 sec
- 60 sec	STORAGE MODE Sample transmissometer voltages Correct signal for 0% and 100% levels Print transmission on paper tape Store transmission in memory Repeat at 1 sec intervals for 180 sec
0 sec	(DIRT-II Event Firing)
120 sec	Conclusion of STORAGE MODE Recheck 0% and 100% levels Record transmission data on mag tape

TABLE III
DIRT-II Transmission Data Summary

TEST	DATE	GMT TIME	COMMENTS
ARTY B1	7-19-79	1824	On target, cloud moved into beam
" B2	"	1830	West of beam 10 m, about 5 sec of data
" B3	"	1837	West of target 20 m, about 10 sec of data
" B4	"	1842	On target - 5 sec of data
" B5	"	1847	West of target 10 m, 5 sec of data
" B6	"	1852	East of target, no data
" B7	"	1857	West of target 5 m, good data shows VIS < IR
" B8	"	1902	East of target, no data
" B9	"	1908	West of target, no data
" B10	"	1913	East of target, no data
" B11	"	1918	West of target 10 m
" B12	"	1923	West of target 10 m - VIS < IR
" B13	"	1928	West of target 10 m - no data
" B14	"	1933	East of target, no data
" B15	"	1939	On target - fast decay 2 sec in beam
" A1	"	2020	East target 10 m, change in wind direction, visibility 36 km, good run shows VIS < IR
" A2	"	2026	West of target 10 m
" A3	"	2031	West of target 30 m
" A4	"	2036	West of target 20 m, change in wind direction, little data, some low dust generated by shock wave
" A5	"	2043	West of target 10 m, shows VIS < IR in diffuse cloud
" A6	"	2047	East of target 10 m, shows VIS < IR
" A7	"	2051	Bullseye
" A8	"	2101	Bullseye - square wave signal, in beam for 7 sec
" A9	"	2106	Bullseye
" A10	"	2112	East of target - little data
" A11	"	2117	East of target, poor data, cloud blown away from optical beam - no data
" A12	"	2123	East of target - little data - shows early spike - no data

Table III (Continued)
DIRT-II Transmission Data Summary

TEST	DATE	GMT TIME	COMMENTS
ARTY A13	7-18-79	2128	Bullseye - very good data shows transmission thru diffuse cloud
A14	"	2134	East of target - cloud blown into path, good data shows early spike
A15	"	2140	Bullseye - good data
A13	7-19-79	1534	Shows VIS < IR
A10	"	1620	Shows VIS < IR
A14	"	1655	Small amount of cloud drifted into path, visibility 52 km, VIS and IR equal
A15	"	1734	Square spike - VIS and IR equal
A12	"	1817	Cloud blown away from path, power failure - no data
A11	"	1849	Visibility 80 km very good data - shows VIS < IR
A1	7-20-79	1517	Visibility 40 km shows VIS slightly < IR
A7	"	1553	Only trace data - small amounts of cloud in path
A2	"	1633	VIS and IR equal - little data
A5	"	1730	Visibility 40 km good data shows IR only slightly better than VIS
A6	"	1809	Airborne shot 2 m above ground, visibility 60 km, shows VIS < IR
A8	7-20-79	1839	Recorder malfunction
A9	7-21-79	1520	VIS and IR equal
A4	"	1553	South van moved here, little data - small amounts of cloud in path
A3	"	1820	Fire on 4th try, visibility 55 km, few data points
B6	7-23-79	1512	Low cloud, IR trace needs rework
B7	"	1540	Visibility 30 km, fine example of IR higher than visible thru diffuse cloud
B8	"	1605	Cloud out of beam, no data
B5	"	1631	Visibility 35 km, good run, unusual IR, VIS slightly higher than IR
E1	"	1713	Lots of black dust, VIS and IR equal at all levels.
E2	"	1738	Visibility 40 km, narrow spike, no data

Table III (Continued)
DIRT-II Transmission Data Summary

TEST	DATE	GMT TIME	COMMENTS
B12	7-24-79	1520	Light drift into beam, IR and VIS are equal here at high transmission levels
B11	"	1548	No wind in test area, IR equal VIS in light areas
B9	"	1616	Visibility 40 km, heavy drift into beam, IR and VIS equal, no data
B10	"	1646	Attenuation mostly from cloud edges, IR greater than VIS in light areas
B1	"	1710	Low cloud, 2 sec trace, VIS and IR equal, no data
B2	"	1736	Wind blew cloud quickly thru path, visibility 45 km, no data
E4	7-25-79	1509	Intermittent dust in path VIS < IR in diffuse cloud
E5	"	1541	Visibility 30 km VIS and IR equal
B3	"	1635	Computer failure - no data
B4	"	1701	Spurious signal on 1.06 μm channel, VIS < IR
E3	"	1734	Slow drift through beam, VIS < IR thru diffuse cloud
E6	"	1809	1.06 μm spurious on high gain, VIS and IR equal
E7	7-26-79	1511	Moist dirt, dark cloud, little smoke, VIS and IR equal
E8	"	1552	Visibility 37 km, quickie, small amounts of grey smoke
C6	"	1625	Not much data, visibility 45 km, signals erratic
C5	"	1655	Moved rapidly across beam, IR < VIS at all transmission levels
C3	"	1725	Rapid pass thru beam, visibility 50 km IR < VIS at all transmission levels
C4	"	1808	Fire on 2nd try, rapid pass- IR and VIS equal
C2	7-27-79	1510	Wet ground in test area, slow drift, visibility 35 kms. IR < VIS at low transmission

Table III (Continued)
DIRT-II Transmission Data Summary

TEST	DATE	GMT TIME	COMMENTS
C1	7-27-79	1546	Quick pass, indication that IR < visible for 7 sec, wet ground
C8	"	1616	Dark and light areas moved across path, IR < visible for 19 sec
C9	"	1650	Light drift into beam, IR < VIS at high transmission levels
C10	"	1720	Not much data, insignificant drift
C7	"	1752	Low cloud, quick pass through beam - VIS and IR equal
E11	7-28-79	1532	Quick pass thru beam - VIS and IR equal
E9	"	1602	Large diffuse cloud thru beam, good data - VIS < IR at all levels
E10	"	1633	Visibility 45 km, small diffuse cloud, VIS < IR little data
E12	"	1716	Diffuse cloud thru beam, VIS < IR at higher transmission levels
C12	"	1749	Small cloud, slight amount of data - VIS and IR equal at high level

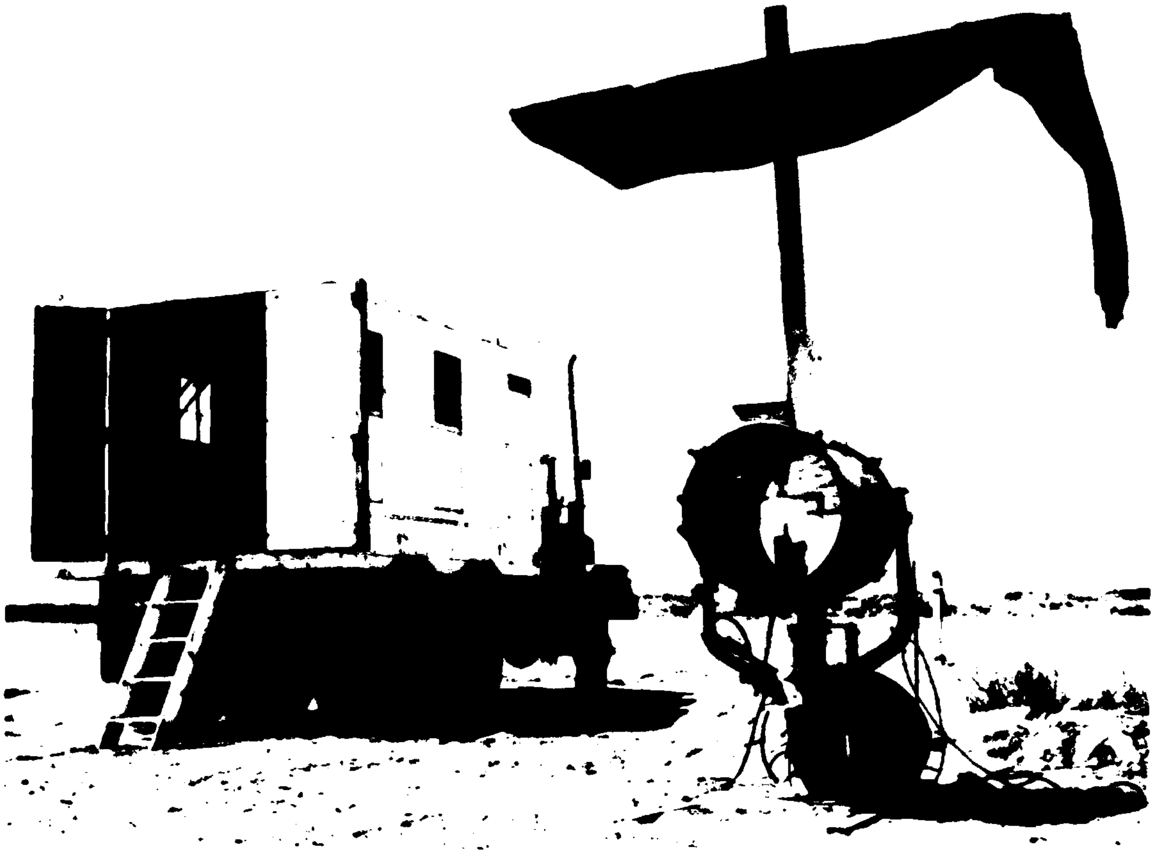

Fig. 1 — Transmissometer source at north end of Dirt II test site

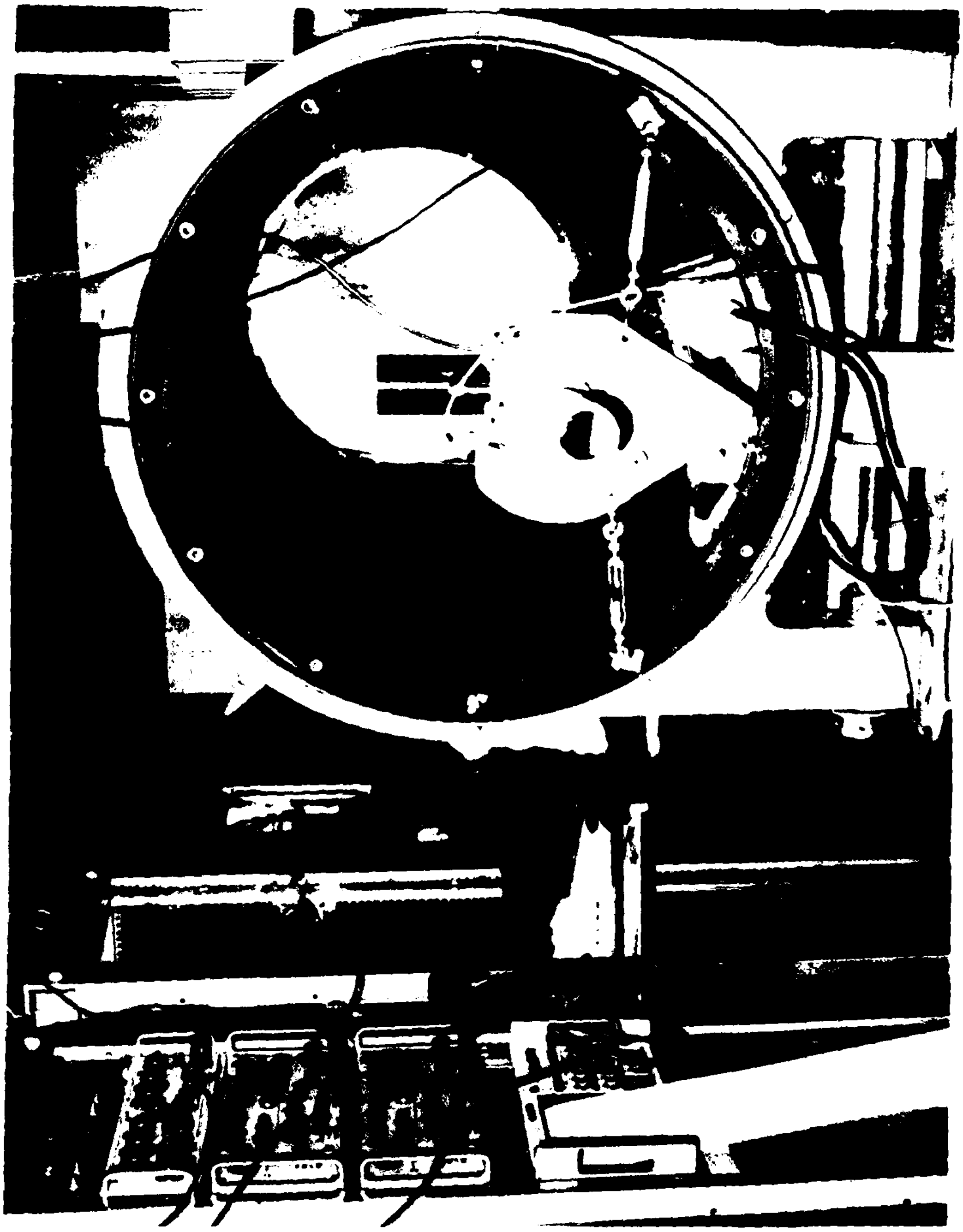

Fig. 2 — Transmissometer receiver at south end of Dirt II test site

Fig. 3 — Receiver electronics and data recording equipment

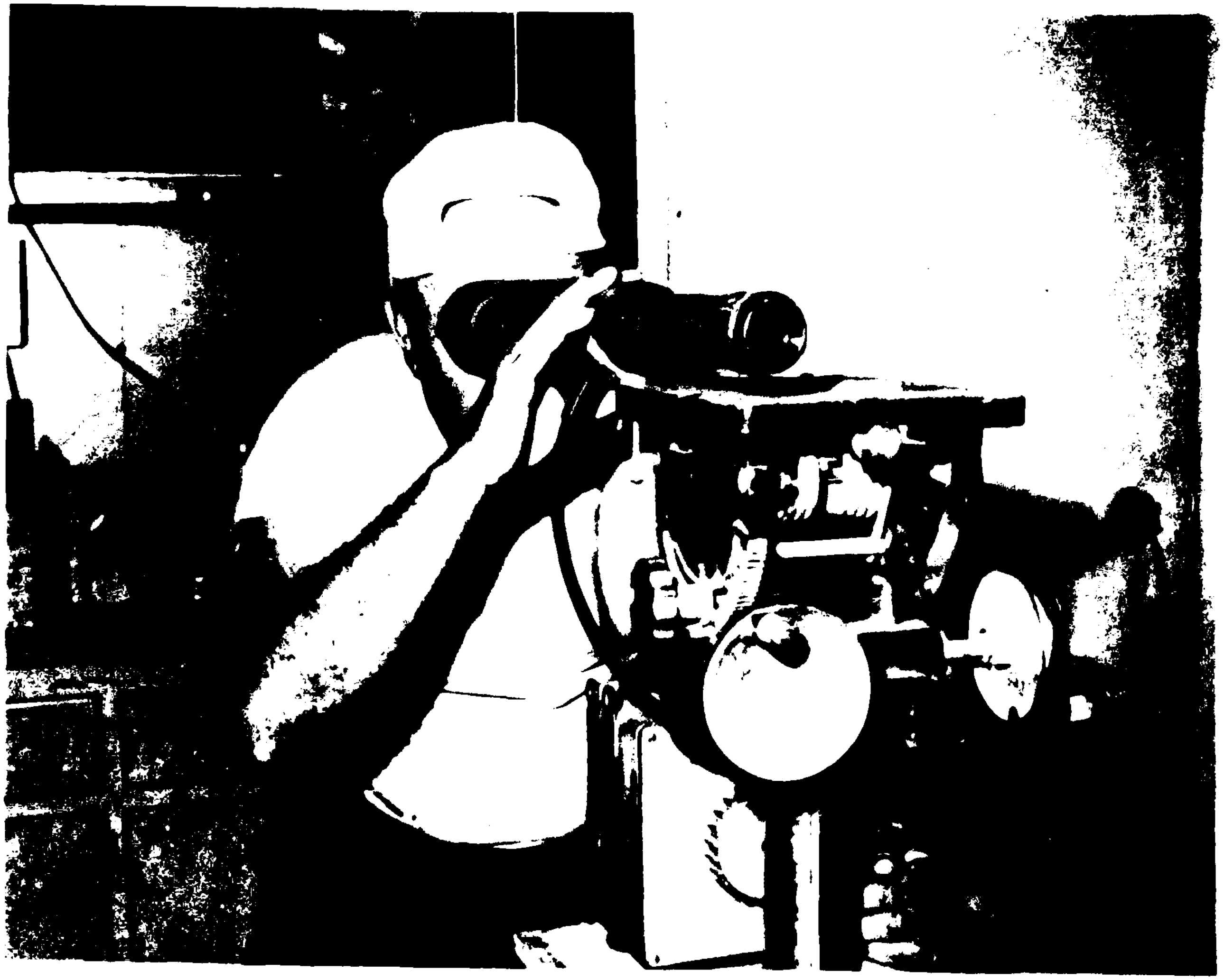

Fig. 4 — Visibility telephotometer in receiver trailer

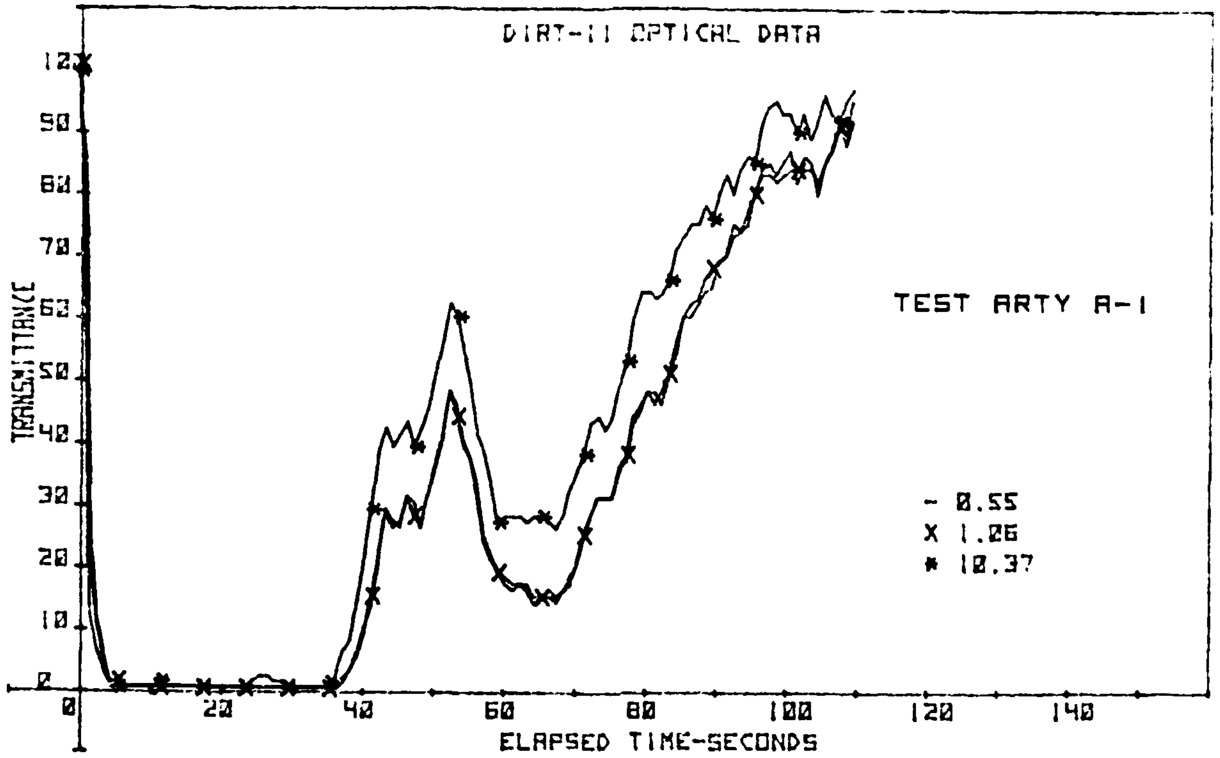

Fig. 5 — 155 mm artillery, 7-18-79, 2020, dry soil

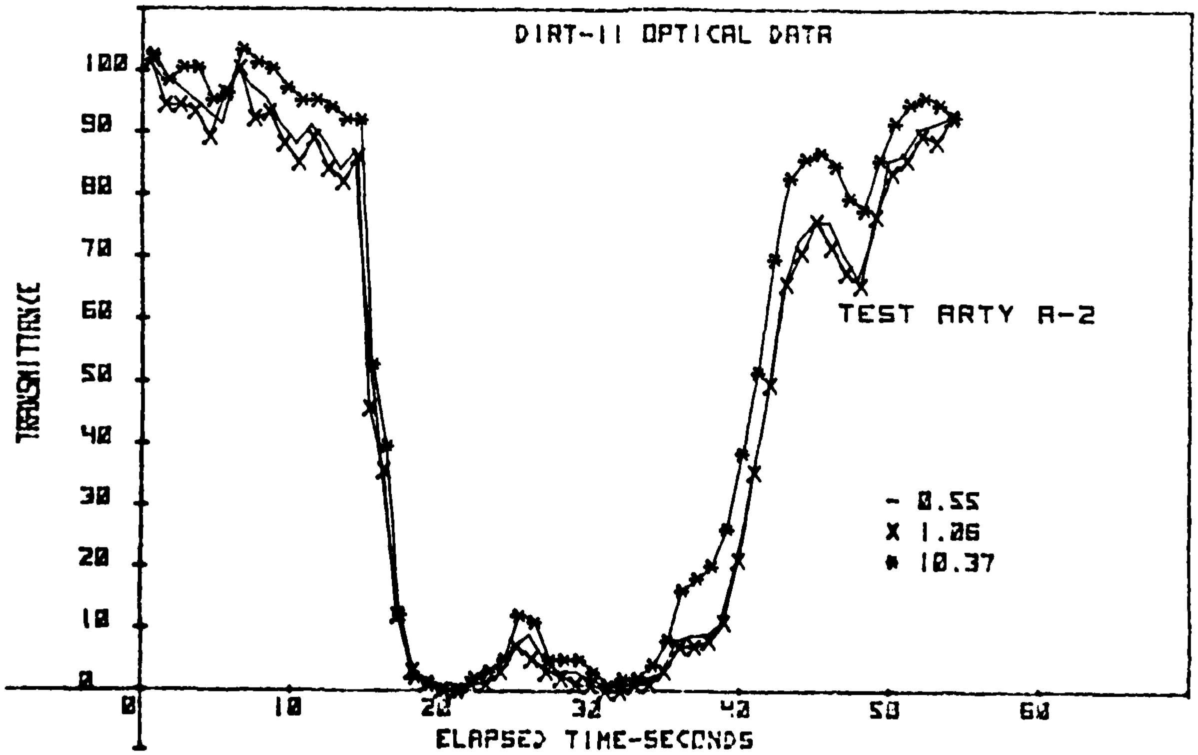

Fig. 6 — 155 mm artillery, 7-18-79, 2026, dry soil

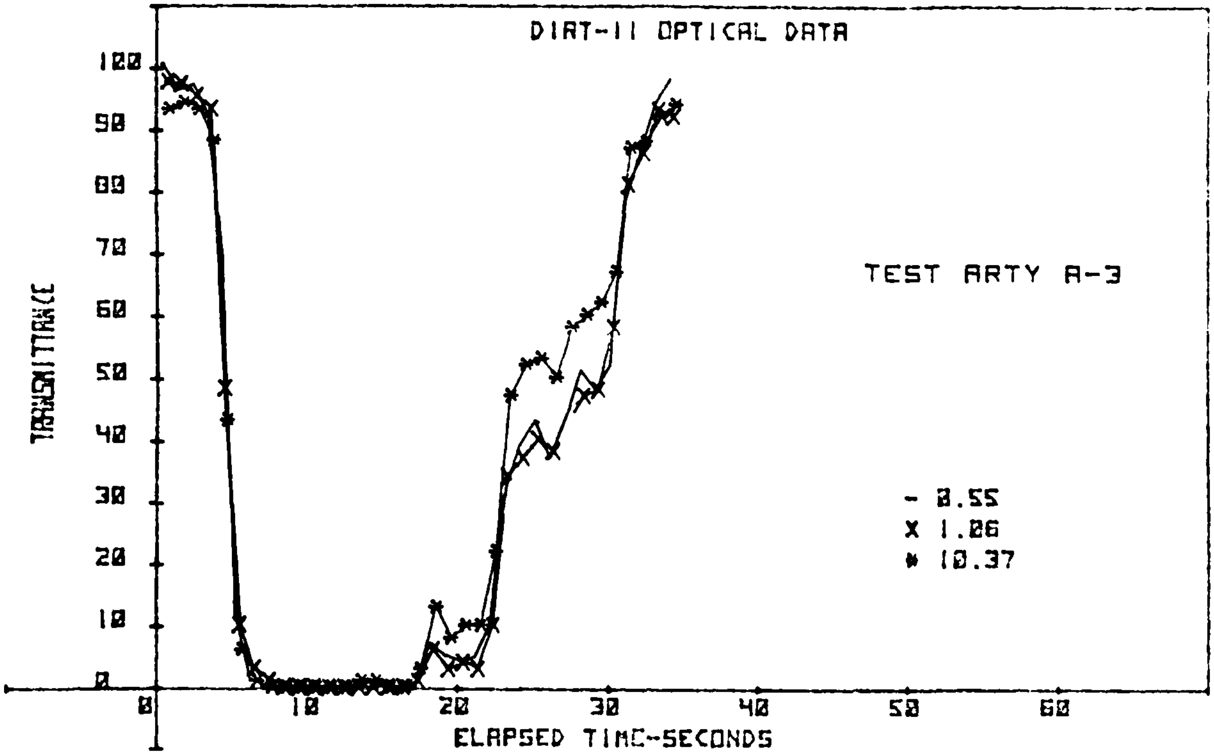

Fig. 7 — 155 mm artillery, 7-18-79, 2031, dry soil

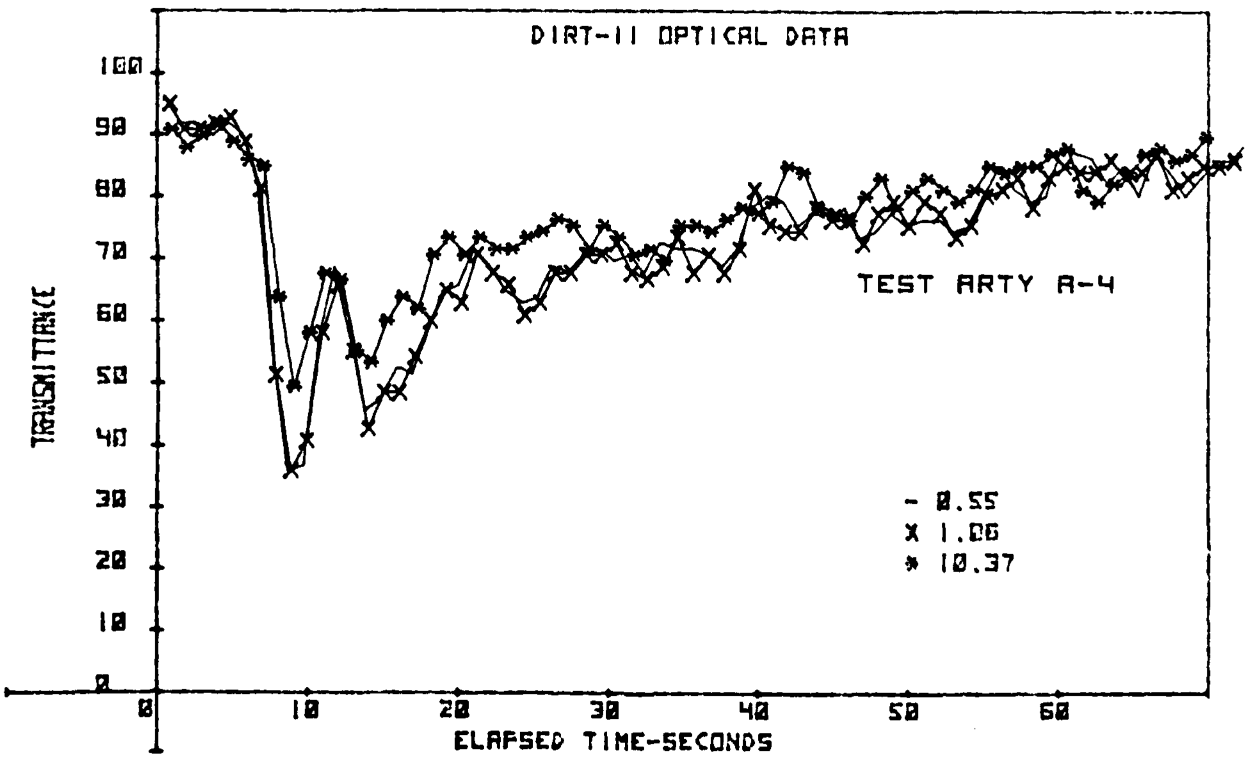

Fig. 8 — 155 mm artillery, 7-18-79, 2036, dry soil

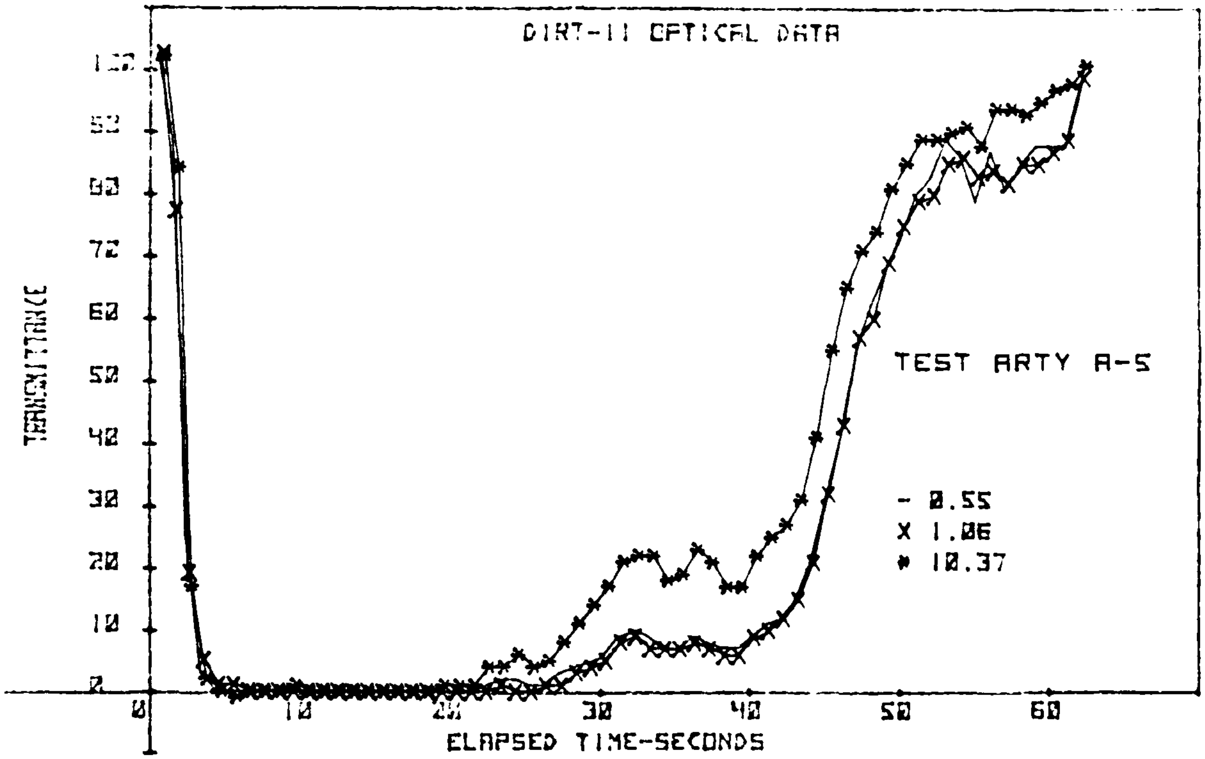

Fig. 9 — 155 mm artillery, 7-18-79, 2043, dry soil

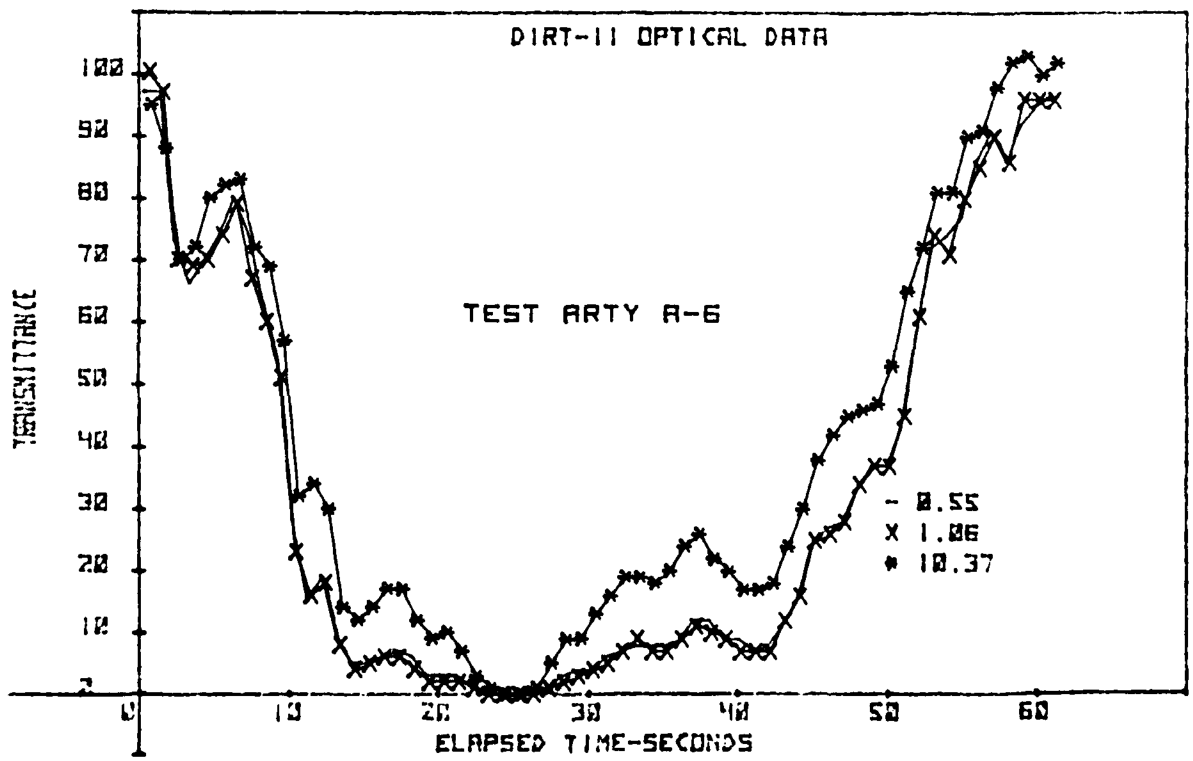

Fig. 10 — 155 mm artillery, 7-18-79, 2047, dry soil

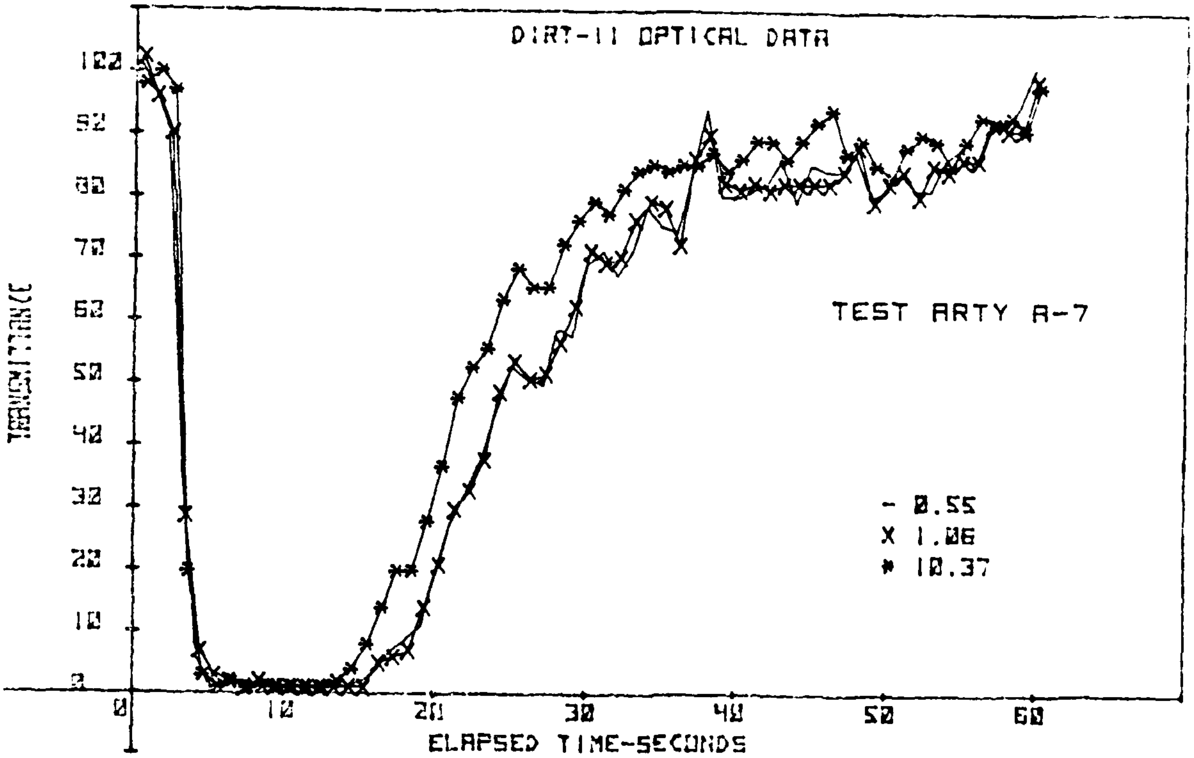

Fig. 11 — 155 mm artillery, 7-18-79, 2051, dry soil

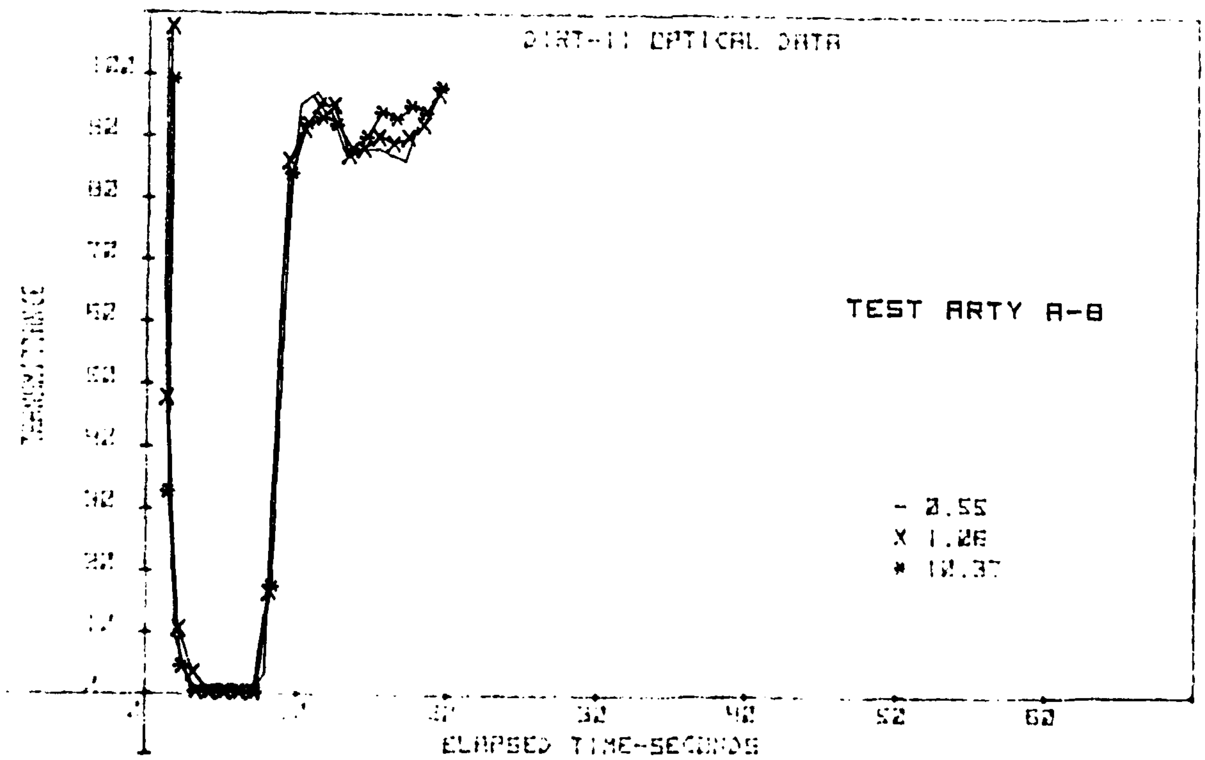

Fig. 12 — 155 mm artillery, 7-18-79, 2101, dry soil

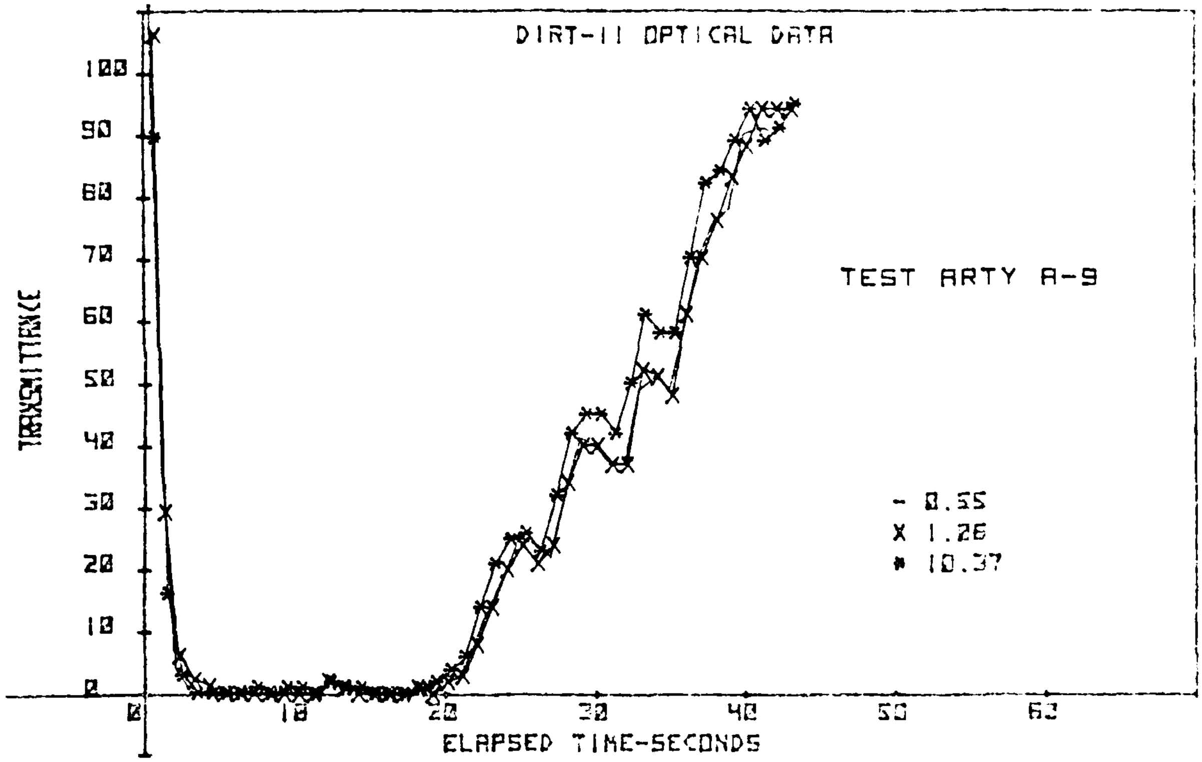

Fig. 13 — 155 mm artillery, 7-18-79, 2106, dry soil

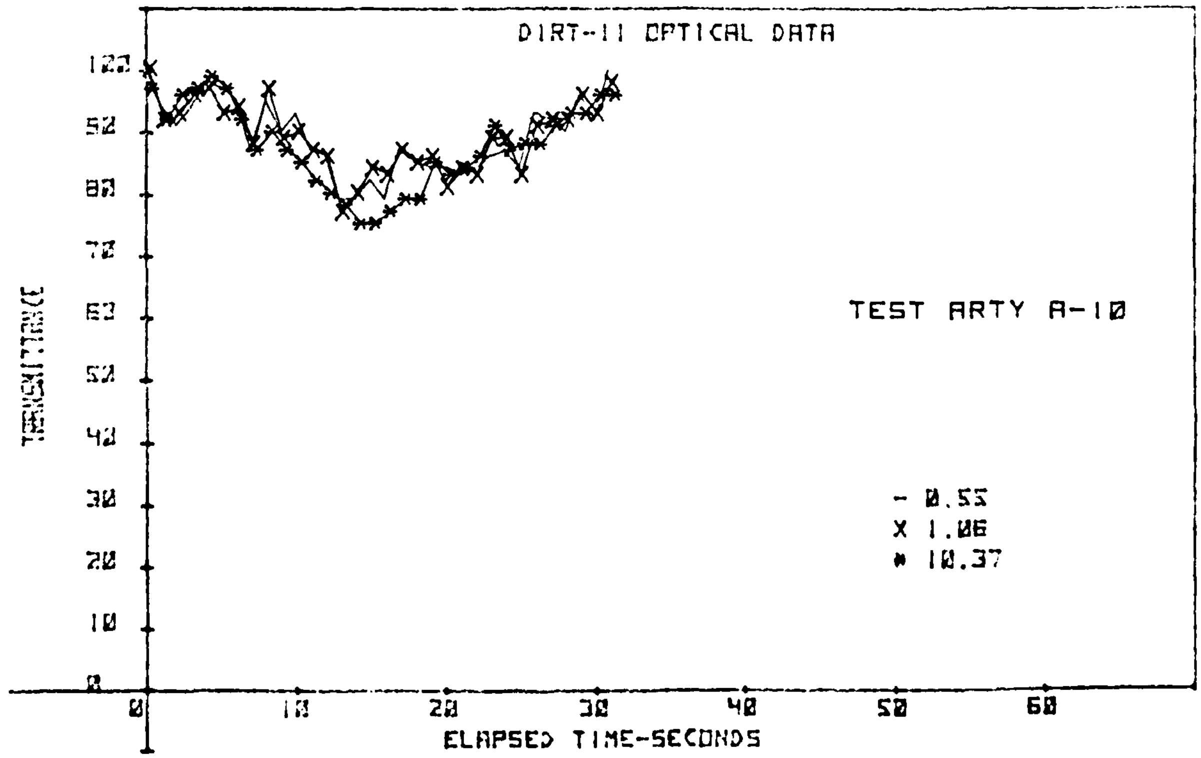

Fig. 14 — 155 mm artillery, 7-18-79, 2112, dry soil

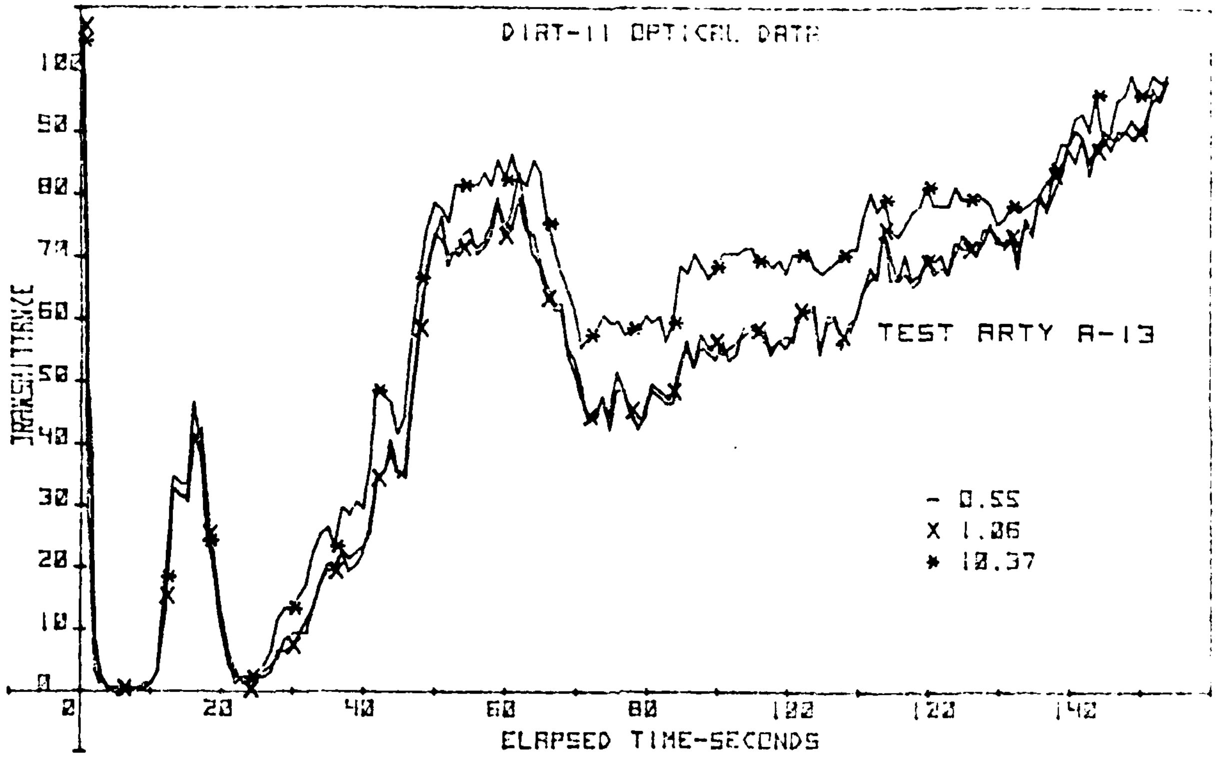

Fig. 15 — 155 mm artillery, 7-18-79, 2128, dry soil

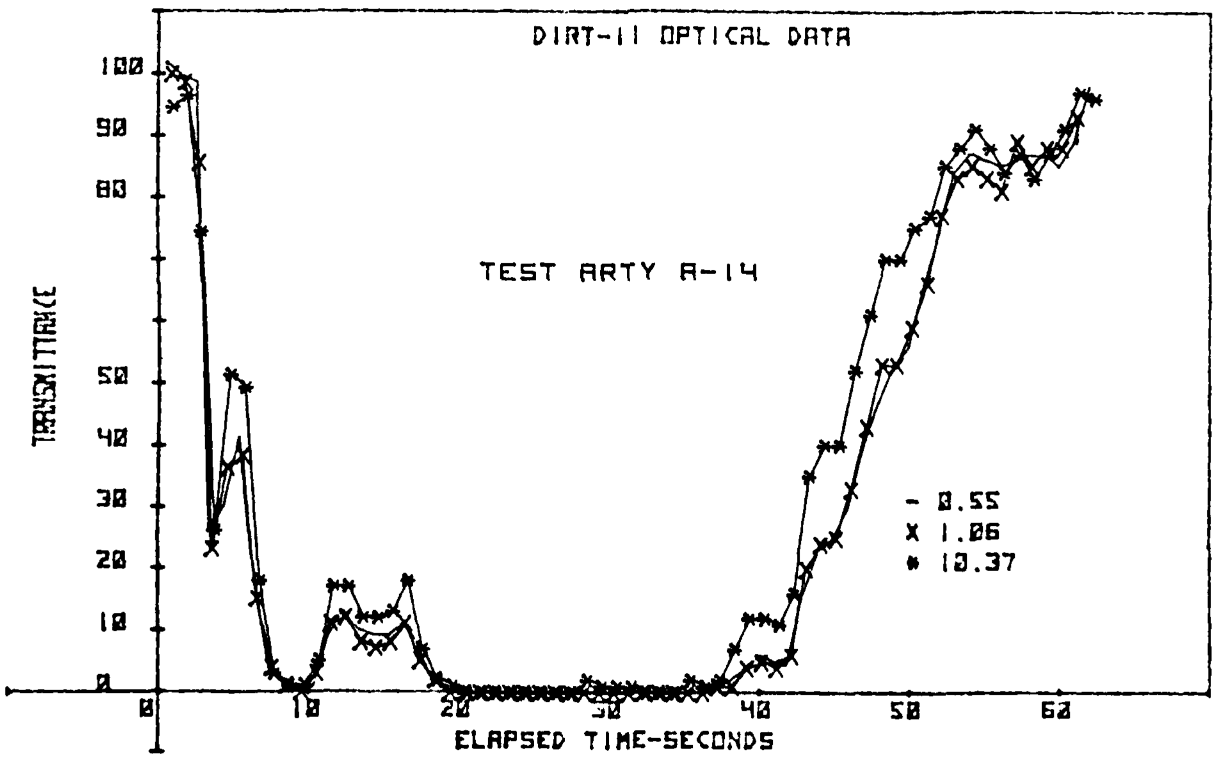

Fig. 16 — 155 mm artillery, 7-18-79, 2134, dry soil

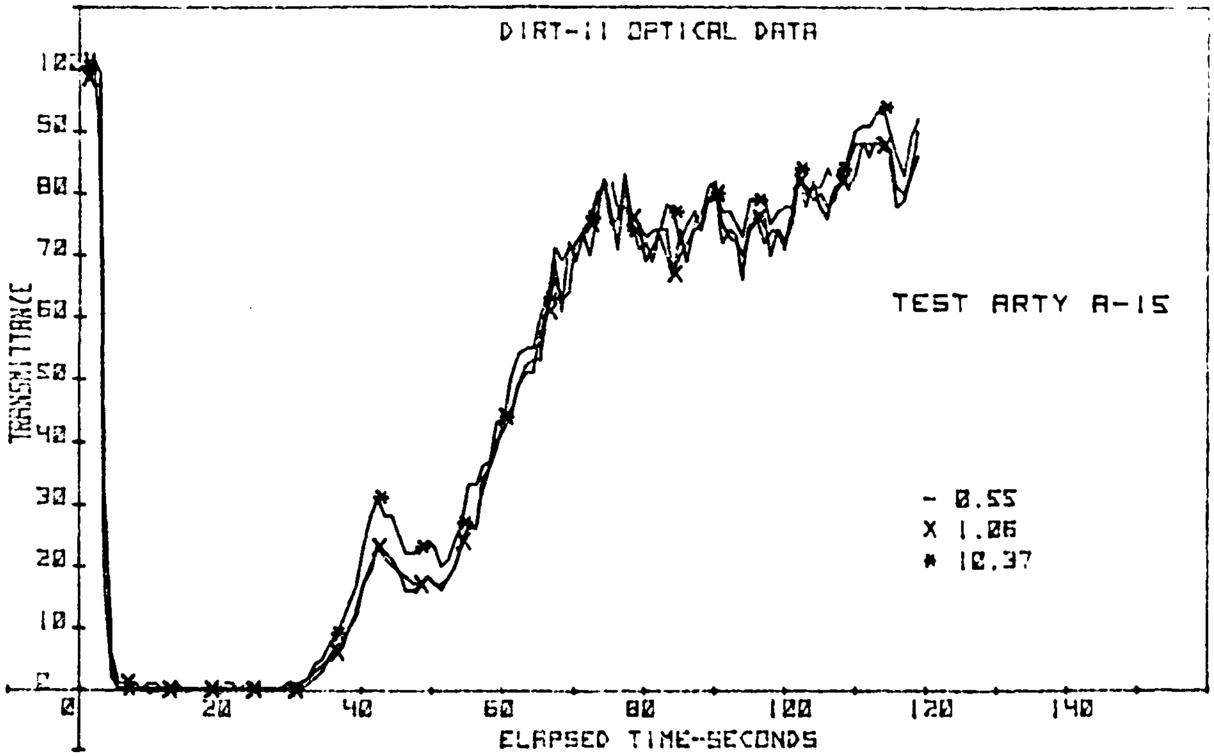

Fig. 17 — 155 mm artillery, 7-18-79, 2140, dry soil

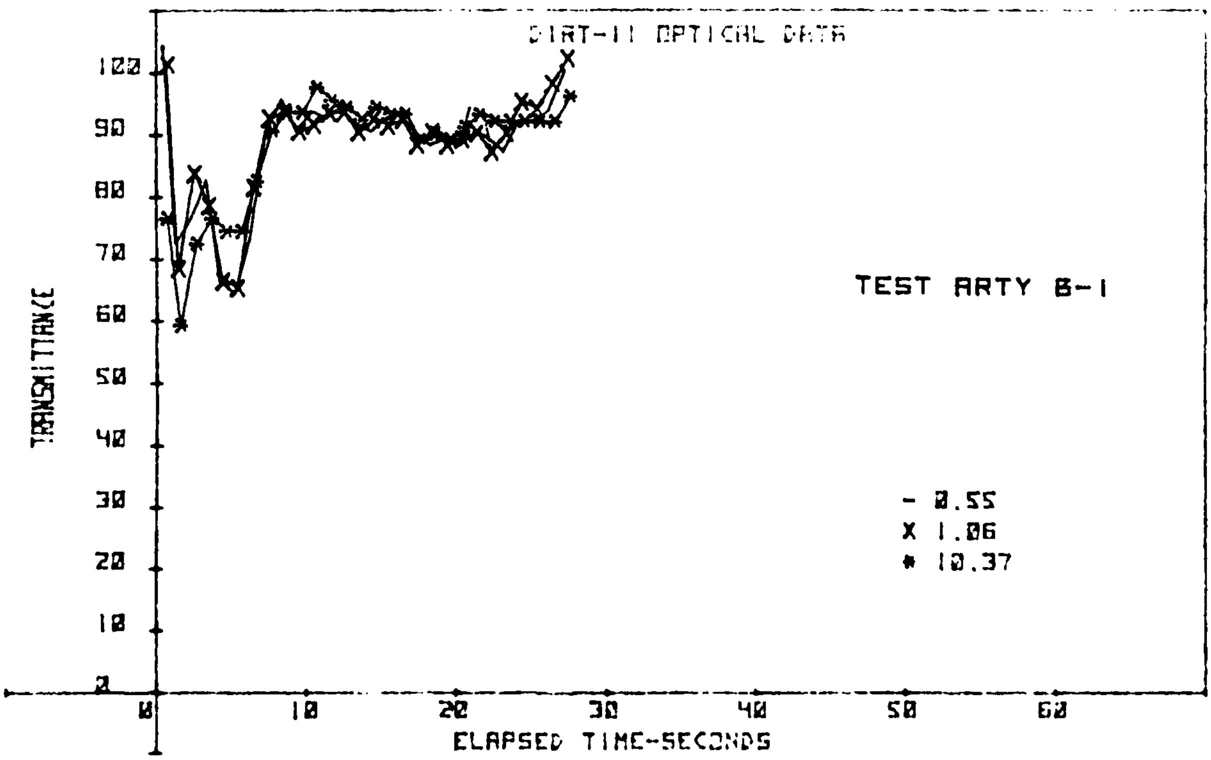

Fig. 18 — 105 mm artillery, 7-18-79, 1824, dry soil

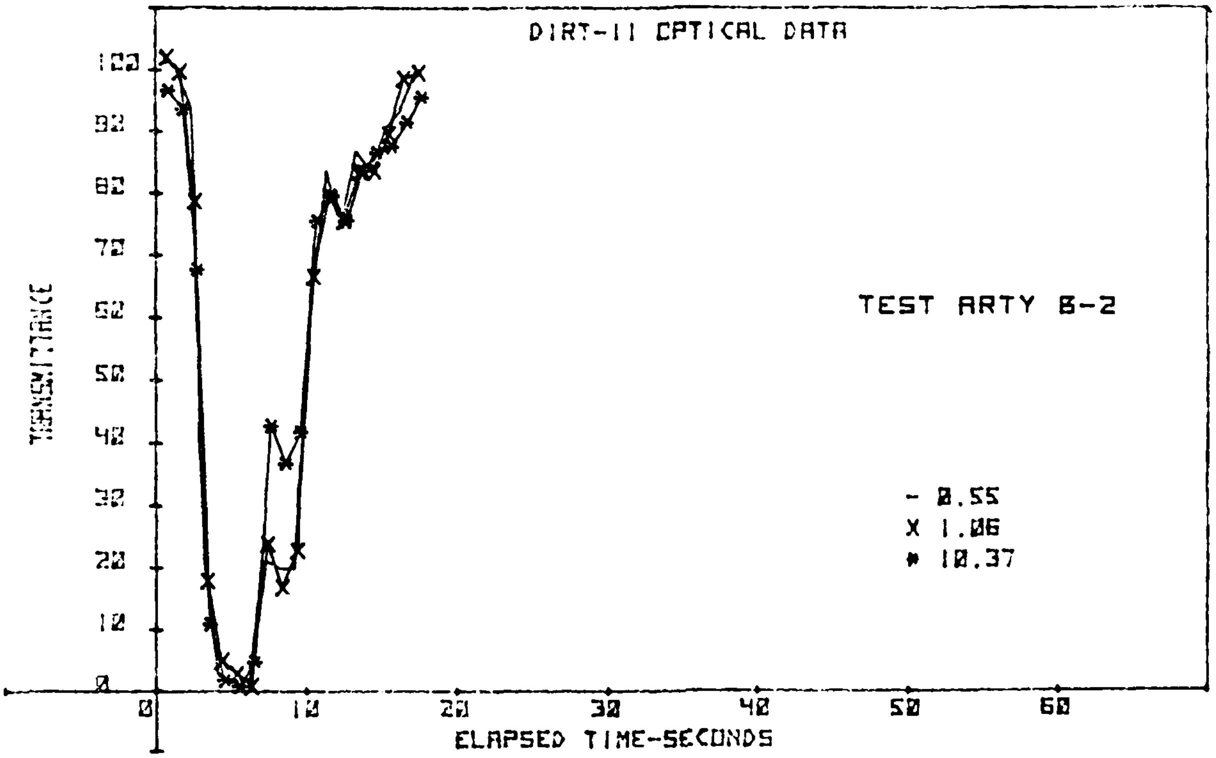

Fig. 19 — 105 mm artillery, 7-18-79, 1830, dry soil

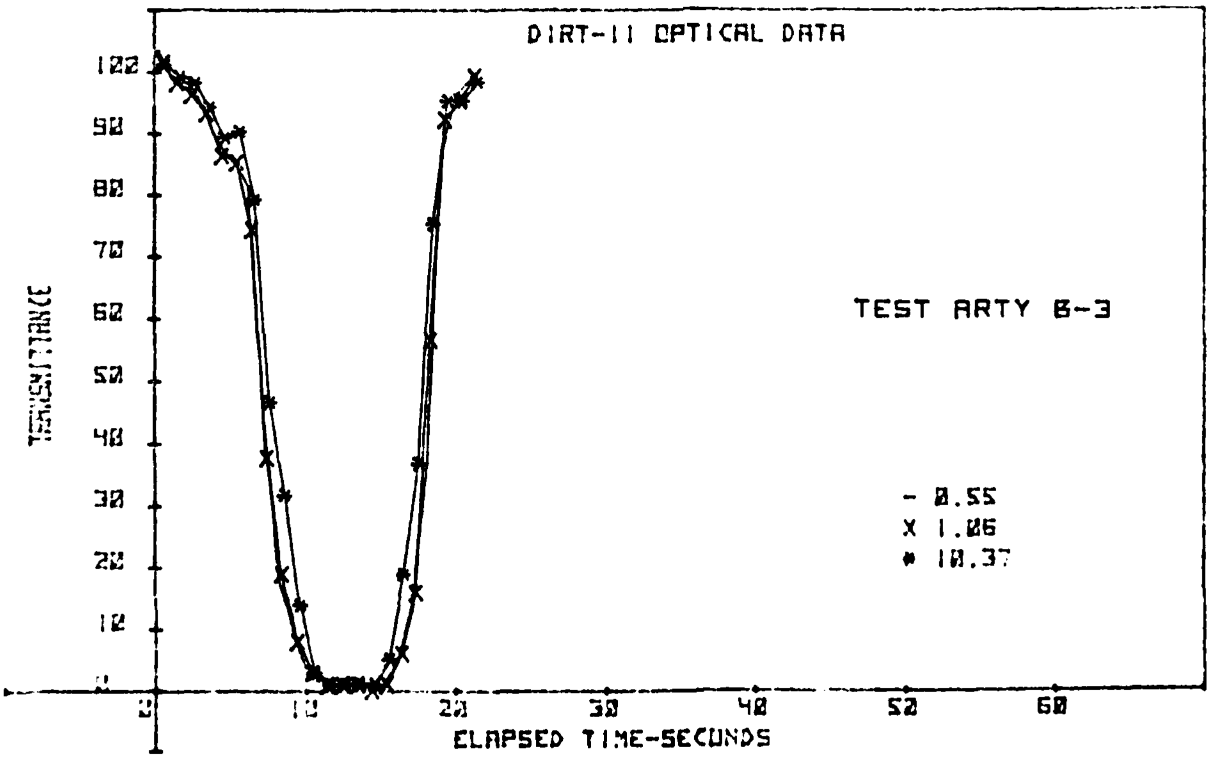

Fig. 20 — 105 mm artillery, 7-18-79, 1837, dry soil

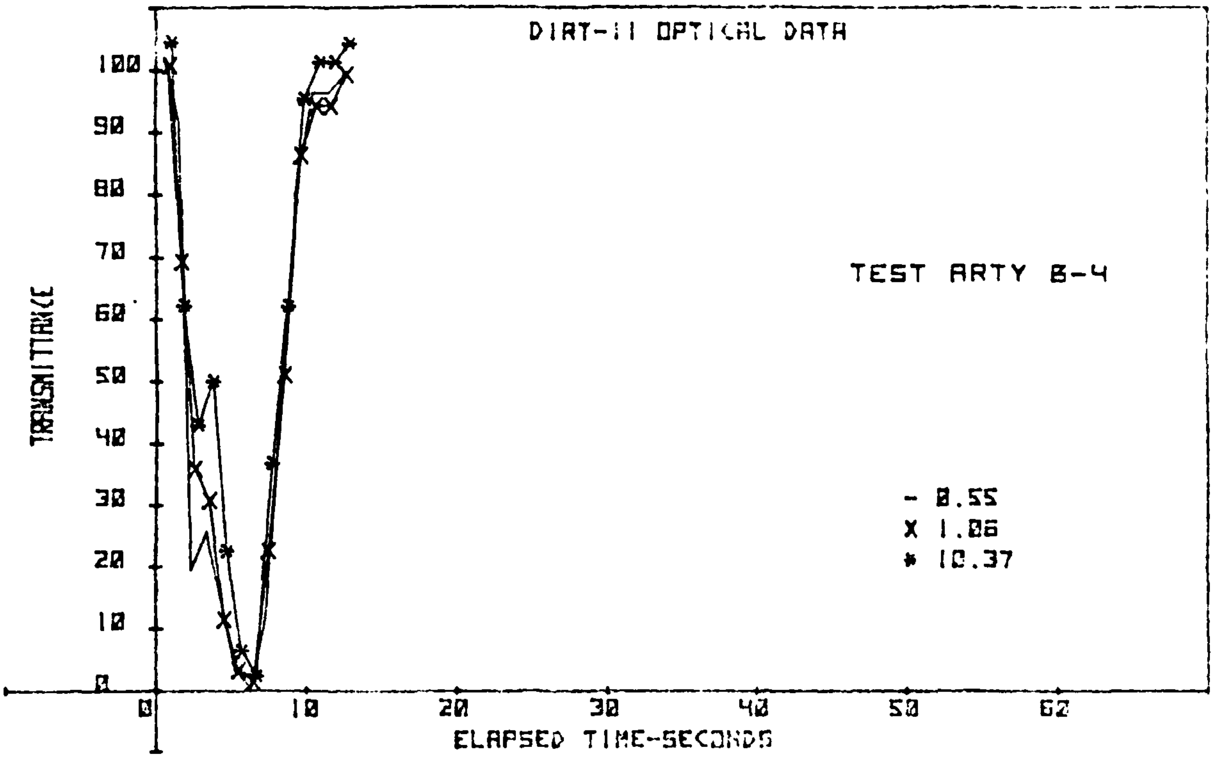

Fig. 21 — 105 mm artillery, 7-18-79, 1842, dry soil

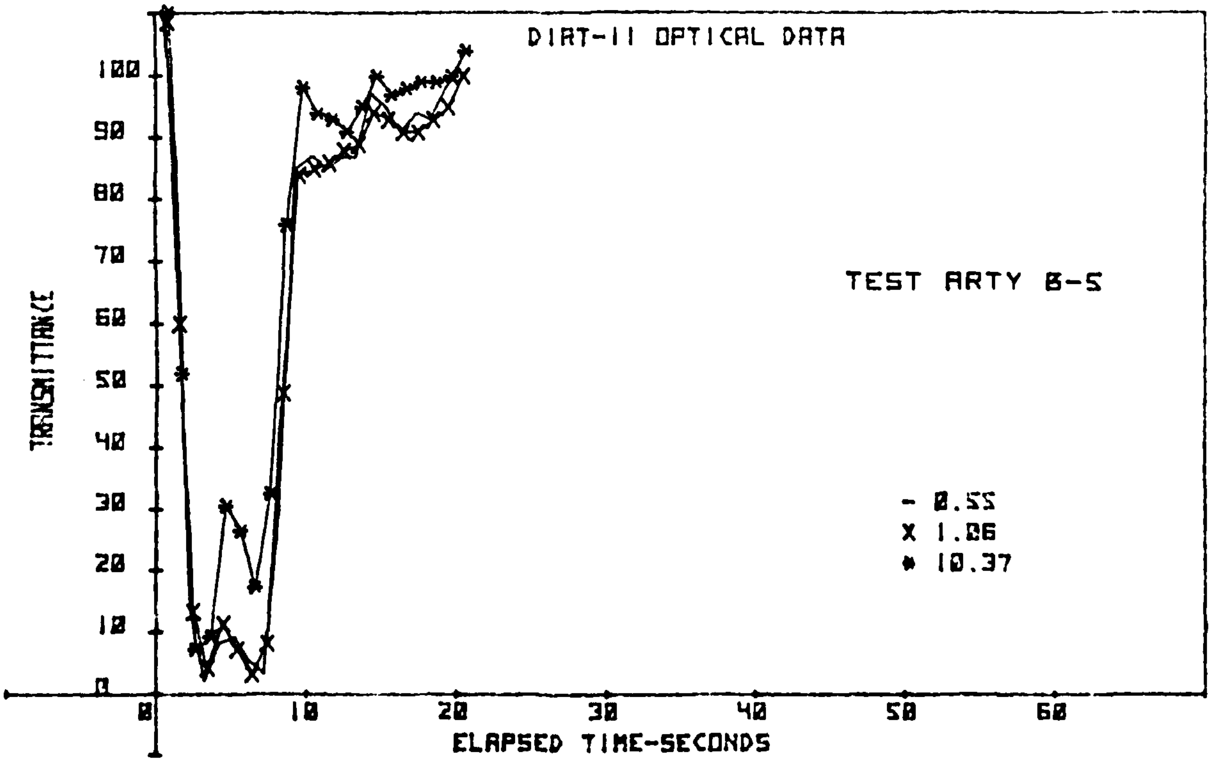

Fig. 22 — 105 mm artillery, 7-18-79, 1827, dry soil

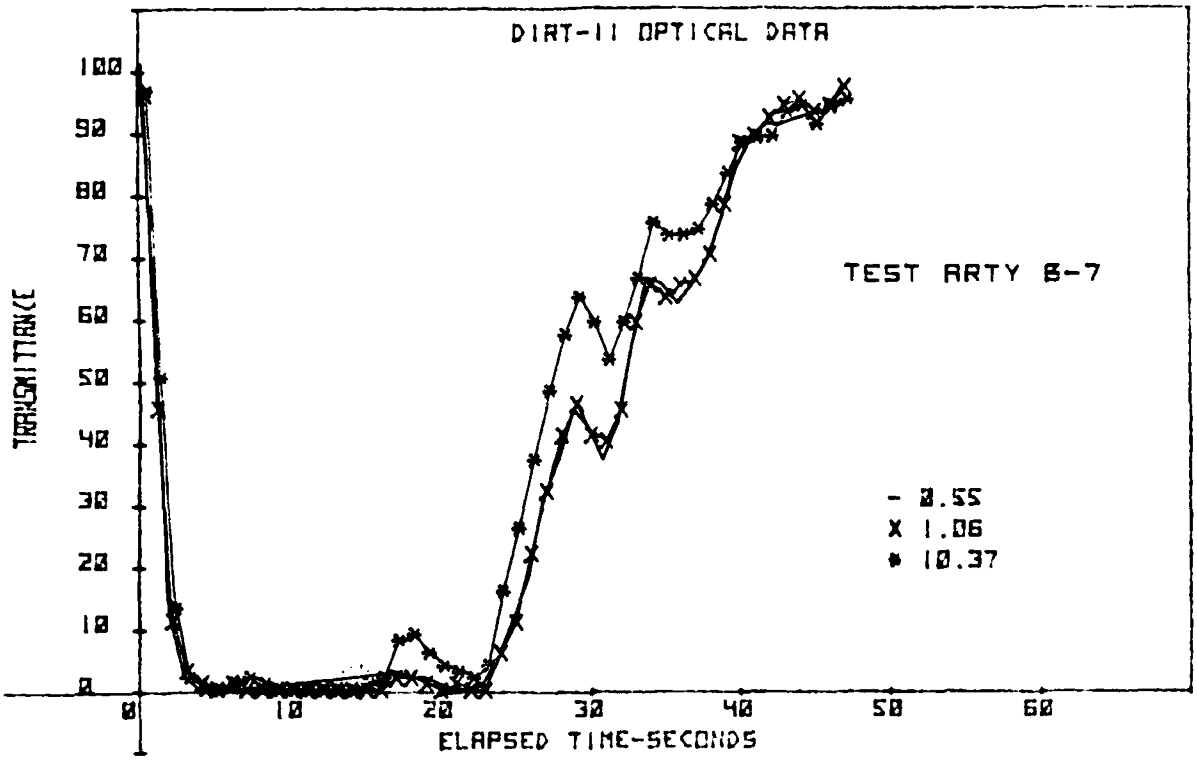

Fig. 23 — 105 mm artillery, 7-18-79, 1857, dry soil

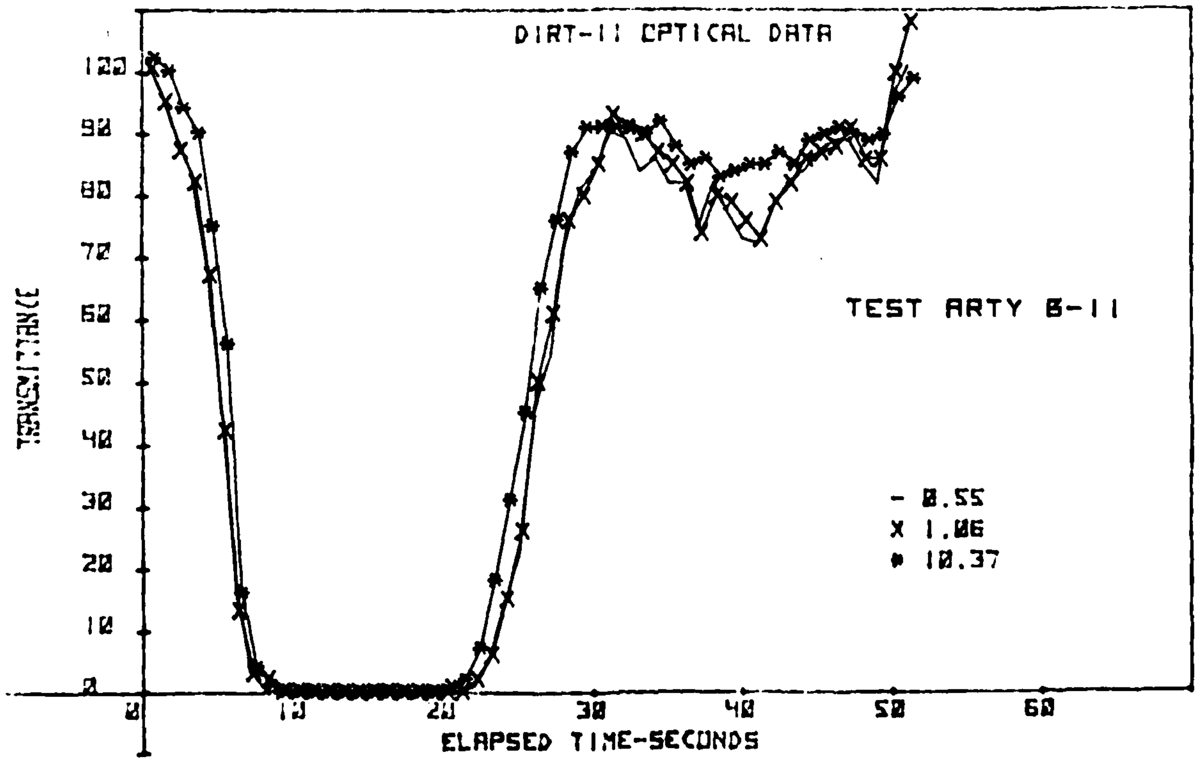

Fig. 24 — 105 mm artillery, 7-18-79, 1918, dry soil

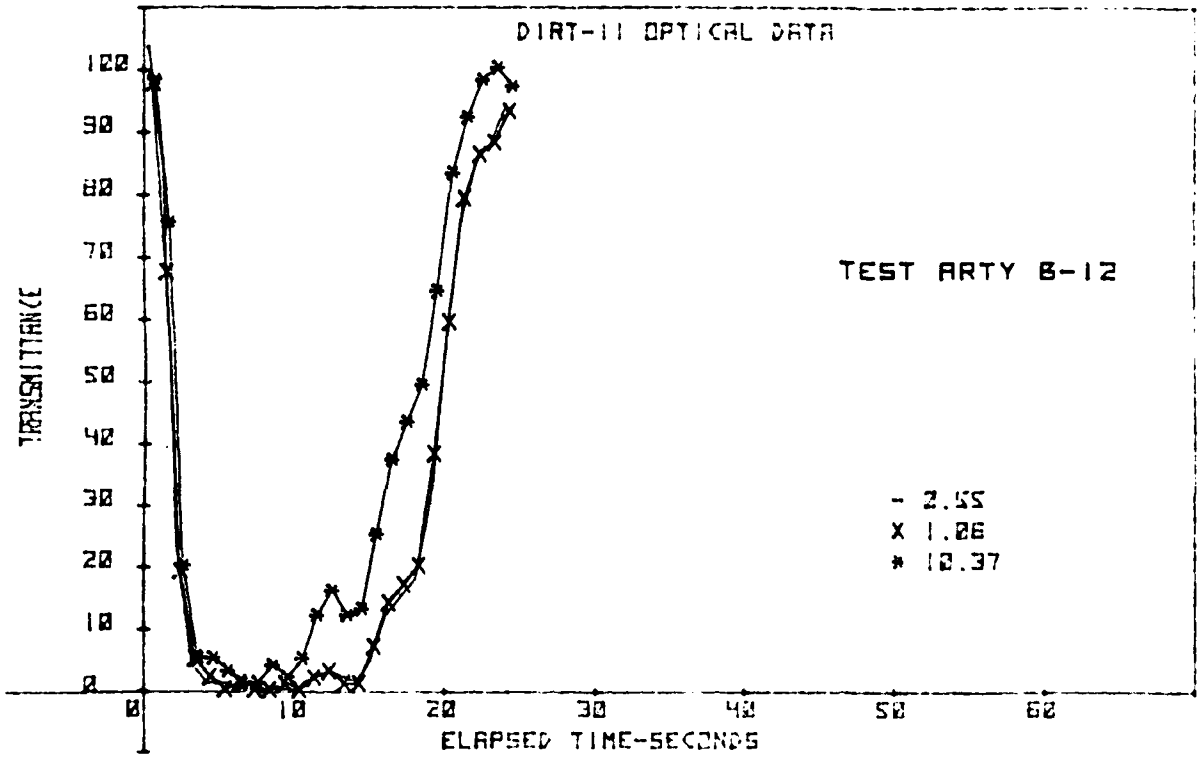

Fig. 25 — 105 mm artillery, 7-18-79, 1923, dry soil

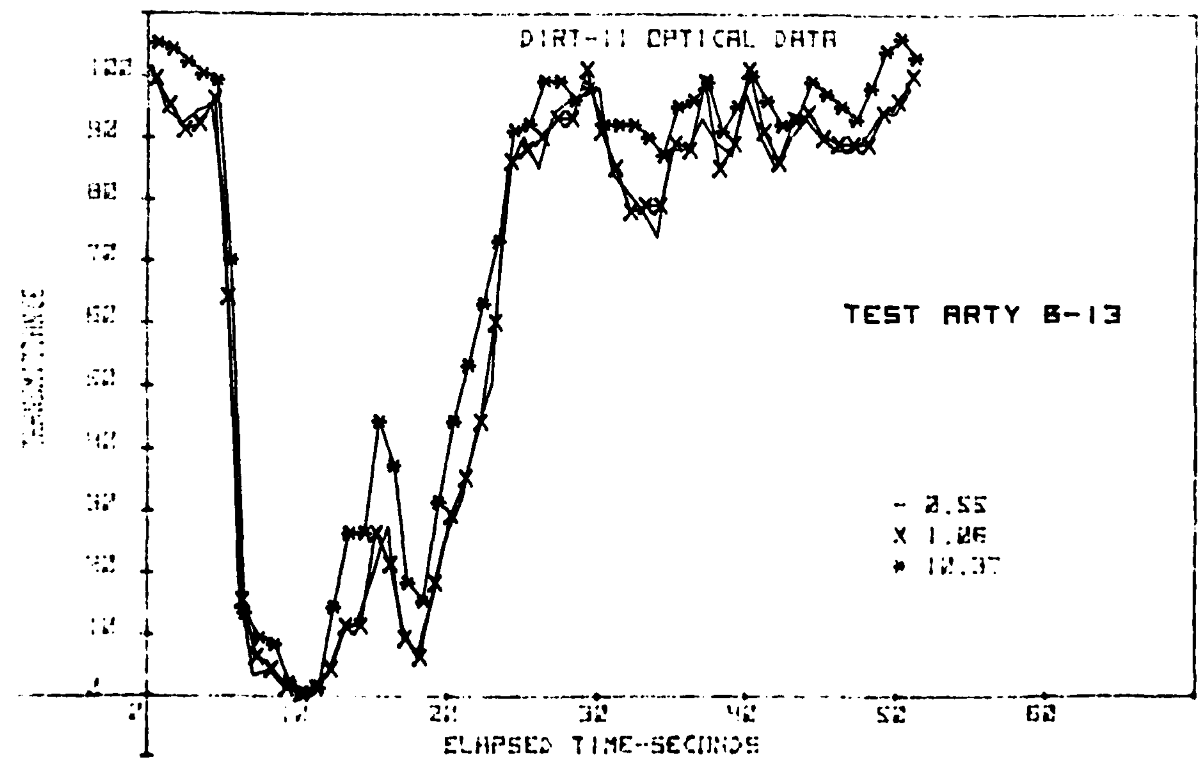

Fig. 26 — 105 mm artillery, 7-18-79, 1928, dry soil

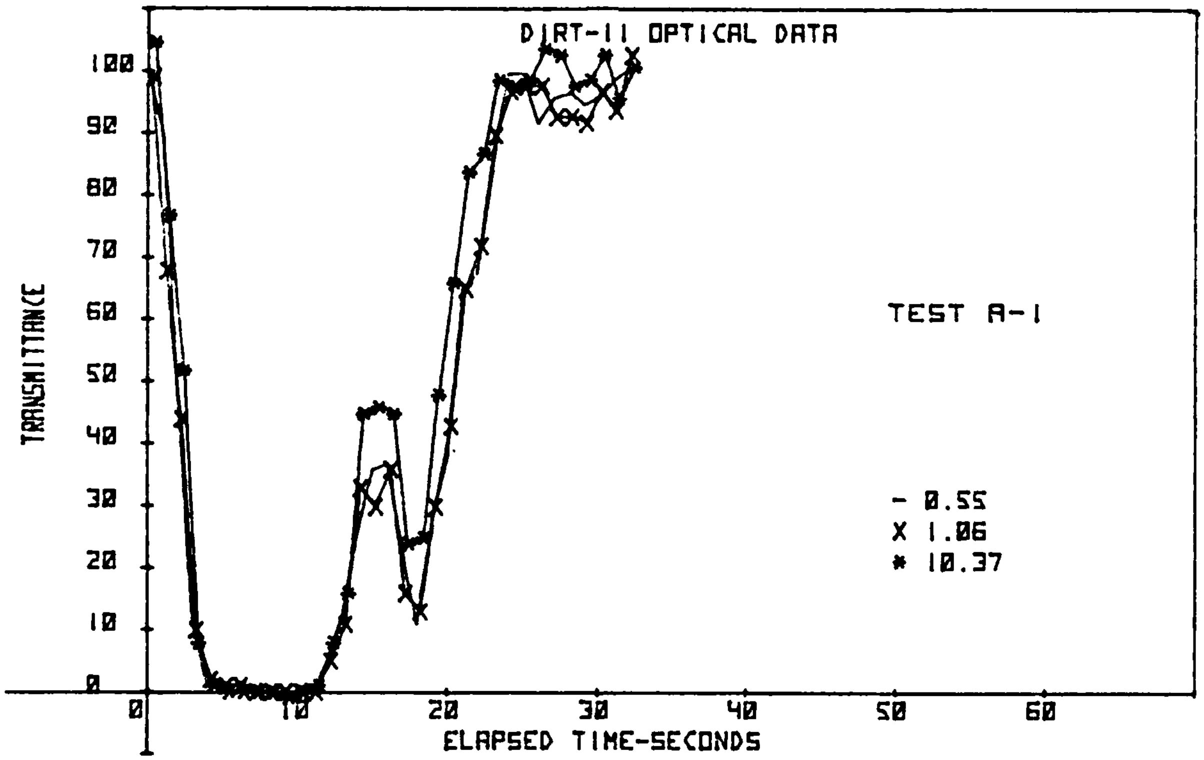

Fig. 27 — 155 mm static 7-20-79, 1517, dry soil

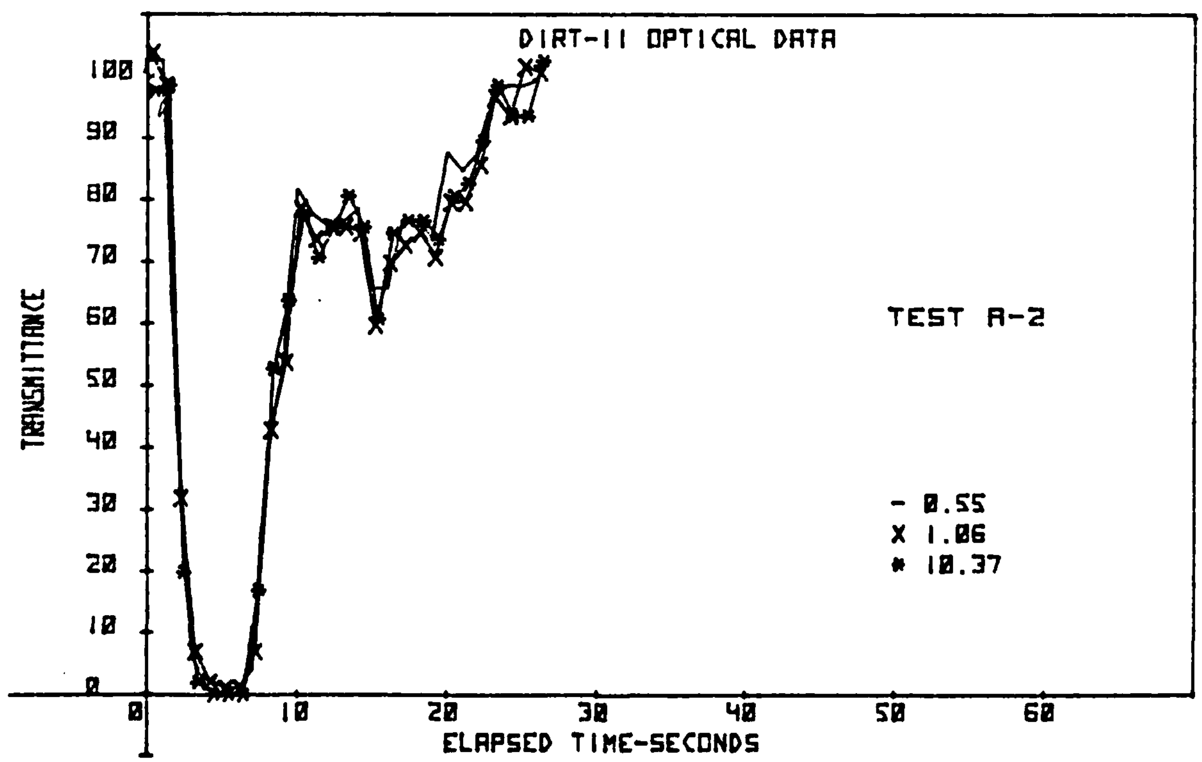

Fig. 28 — 155 mm static 7-20-79, 1633, dry soil

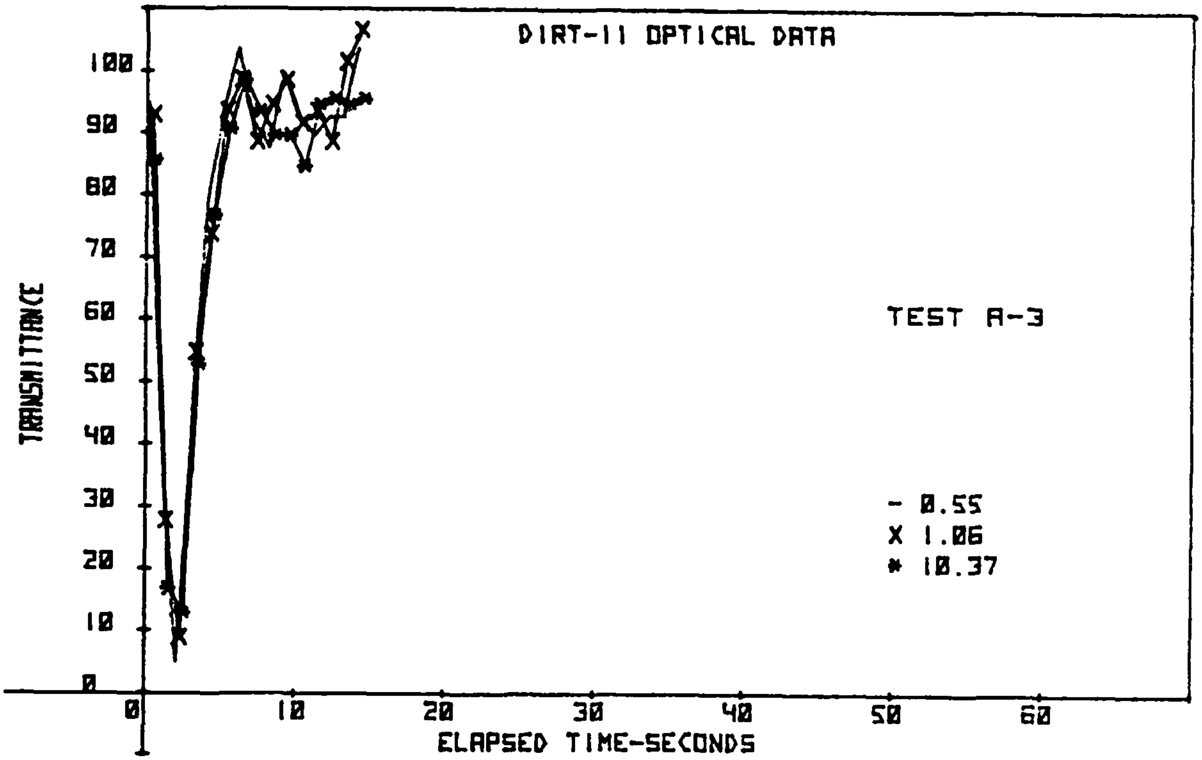

Fig. 29 — 155 mm static, 7-21-79, 1820, dry soil

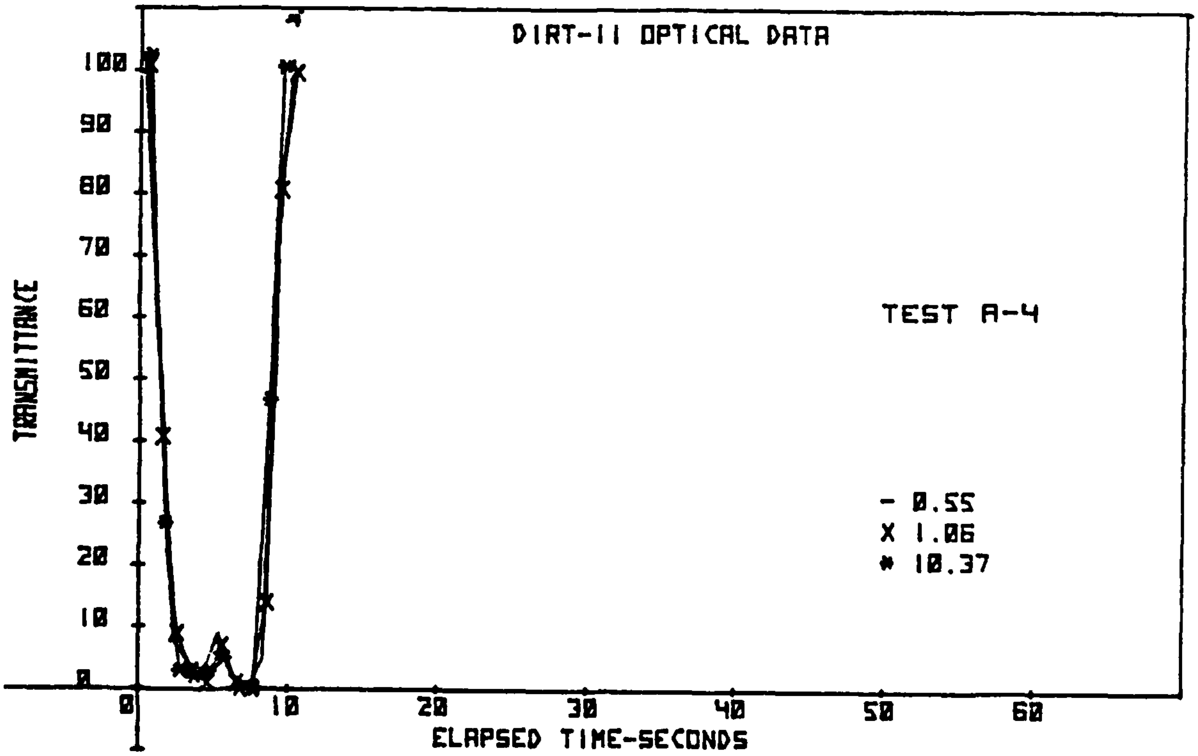

Fig. 30 — 155 mm static, 7-21-79, 1553, dry soil

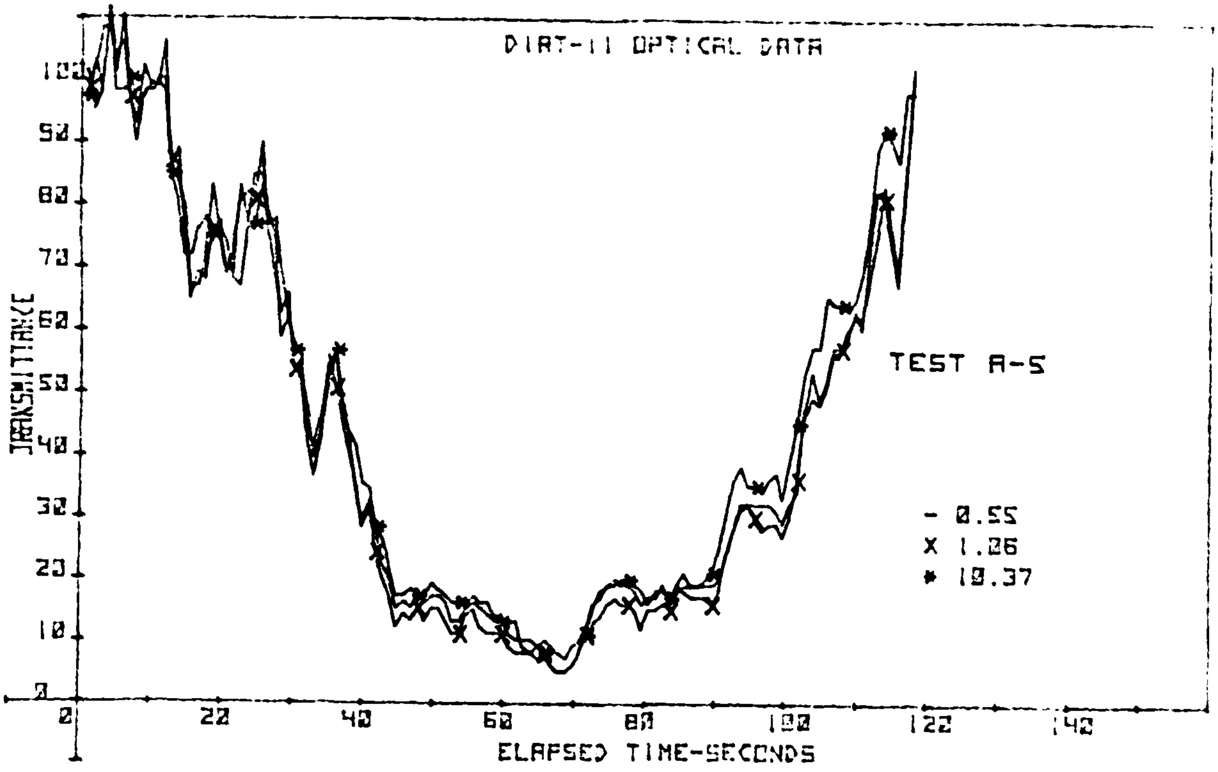

Fig. 31 — 155 mm static, 7-20-79, 1730, dry soil

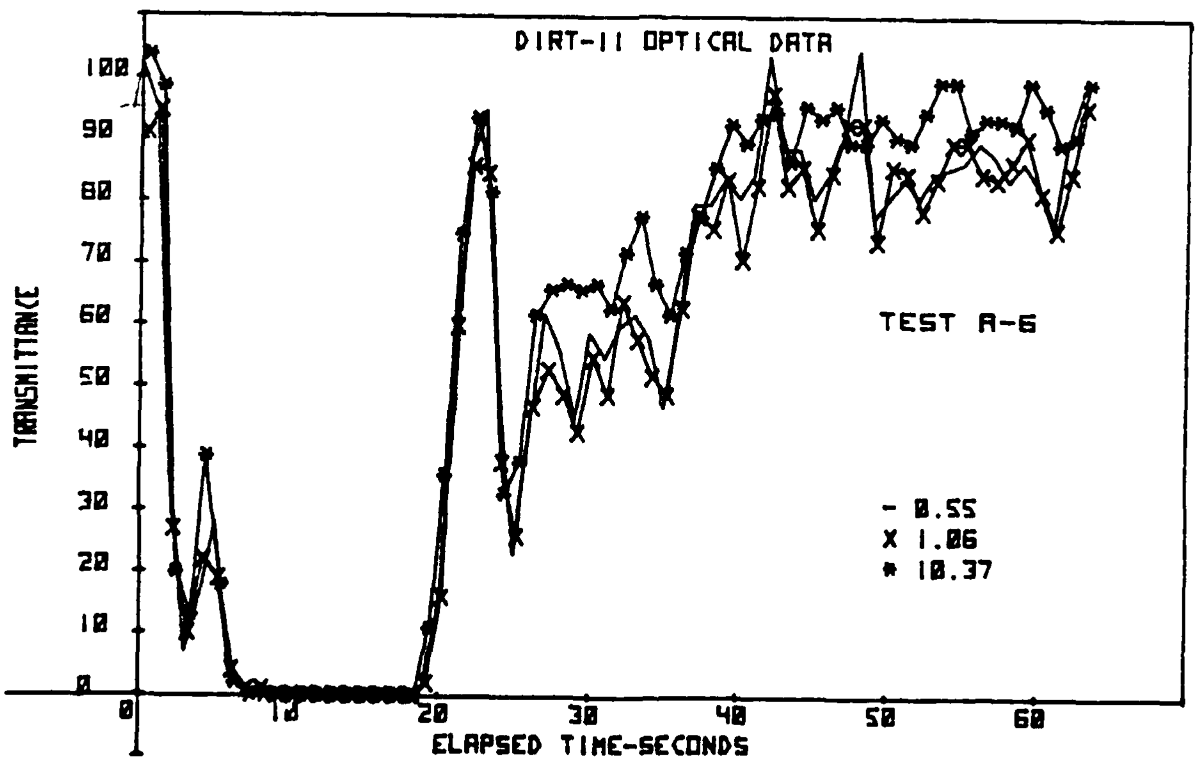

Fig. 32 — 155 mm static, 7-20-79, 1839, dry soil

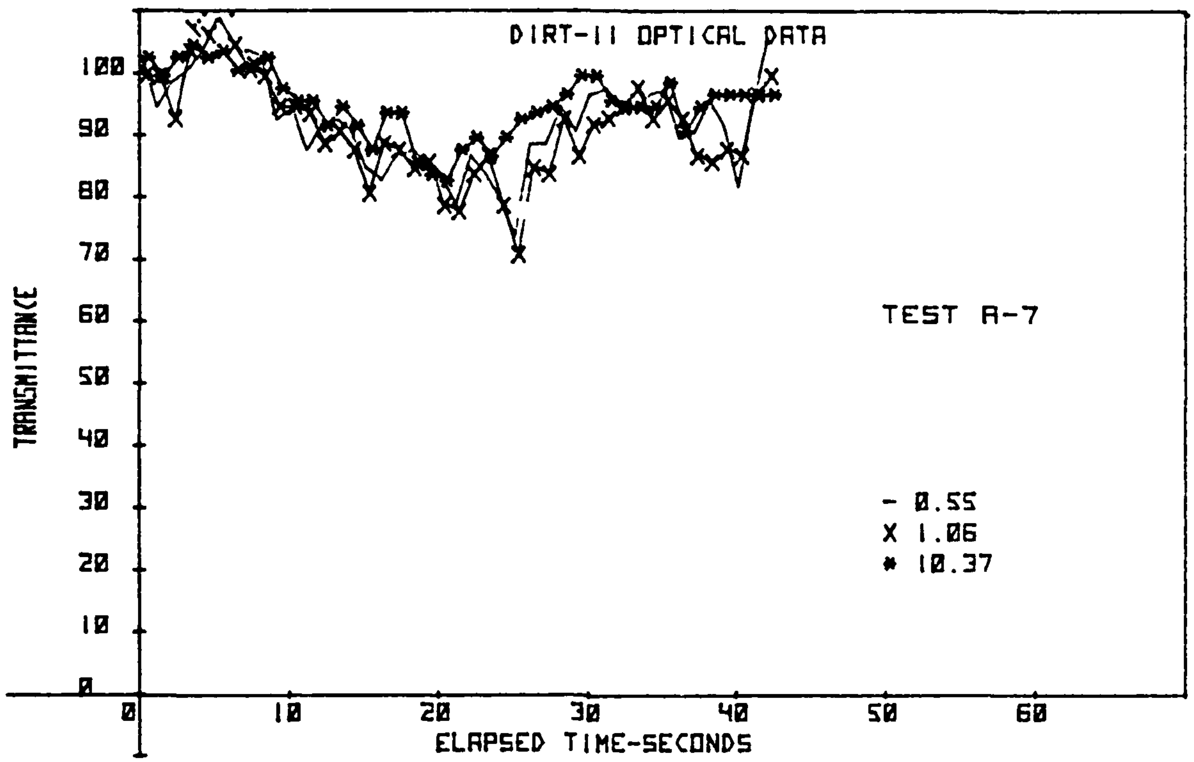

Fig. 33 — 155 mm static, 7-20-79, 1553, dry soil

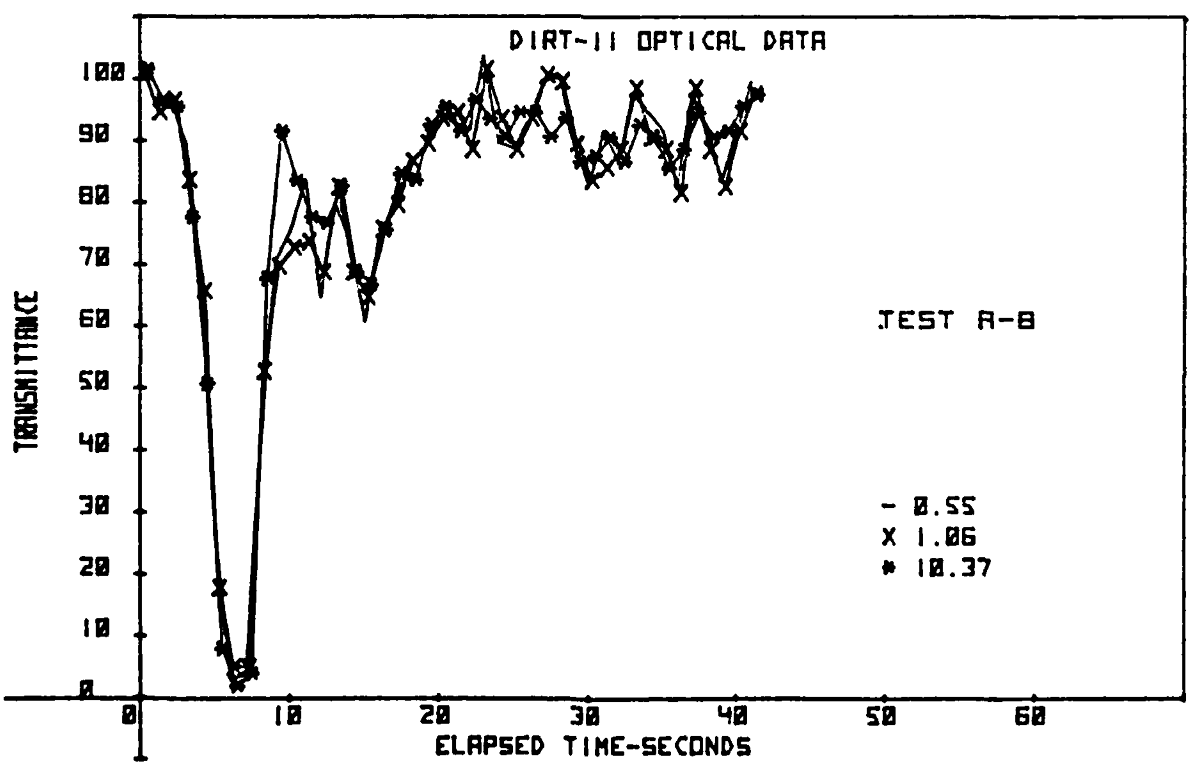

Fig. 34 — 155 mm static, 7-20-79, 1809, dry soil

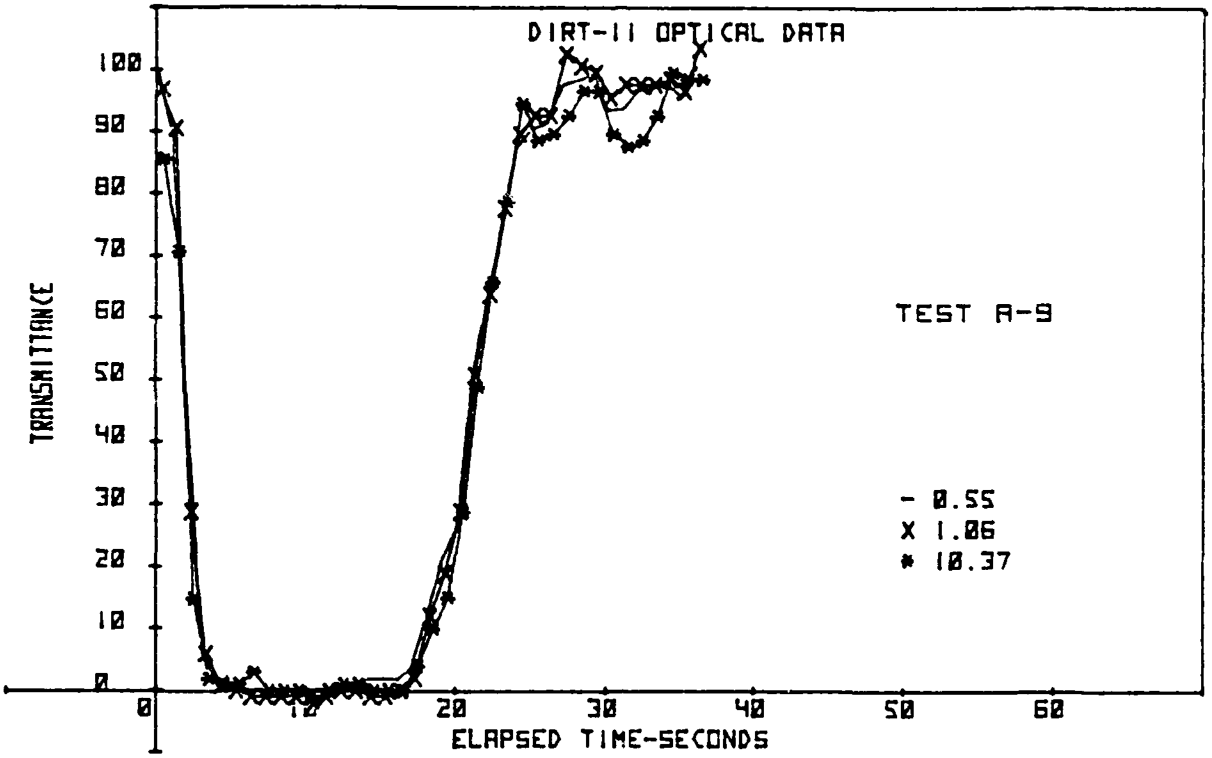

Fig. 35 — 155 mm static, 7-21-79, 1520, dry soil

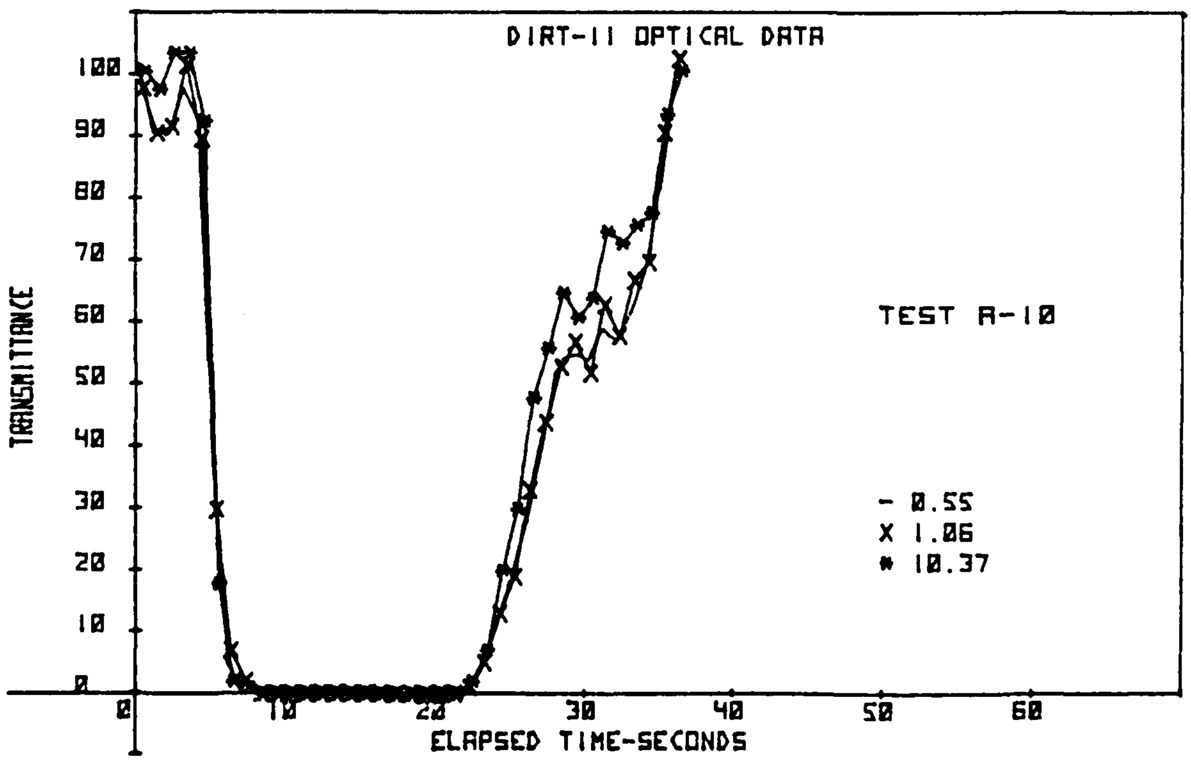

Fig. 36 — 155 mm static, 7-19-79, 1620, dry soil

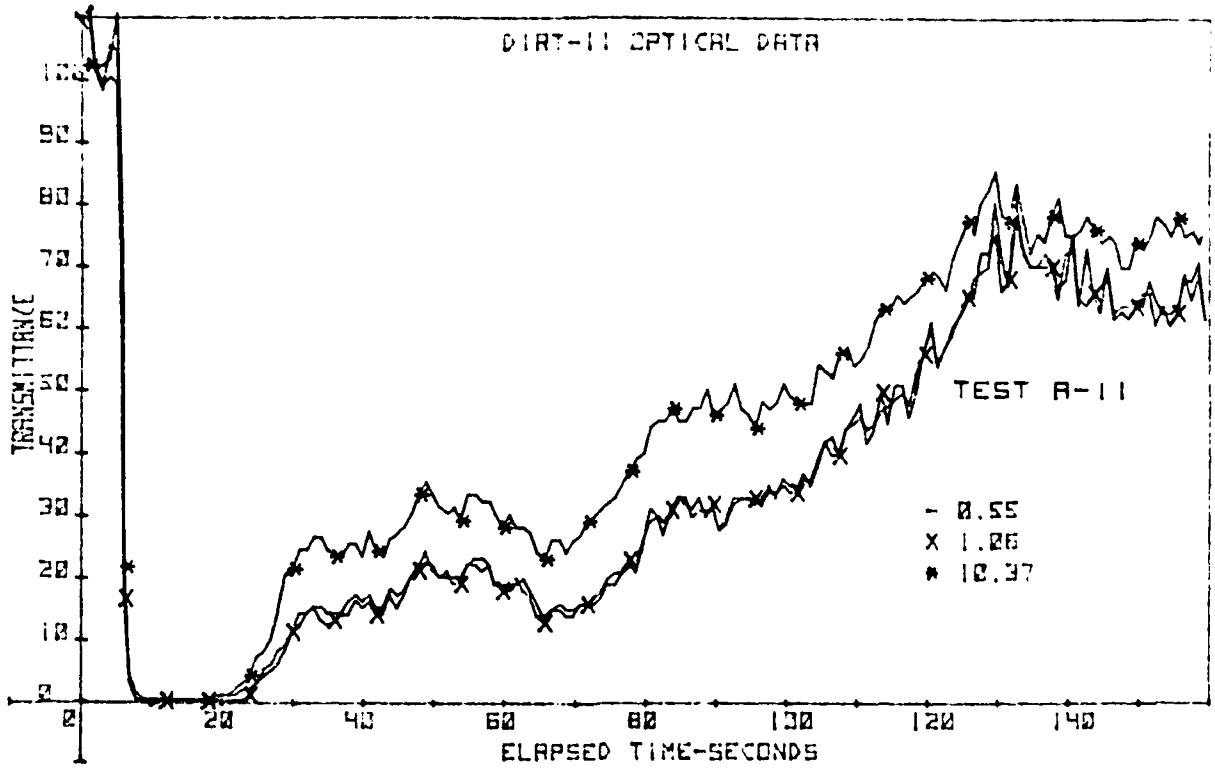

Fig. 37 — 155 mm static, 7-19-79, 1849, dry soil

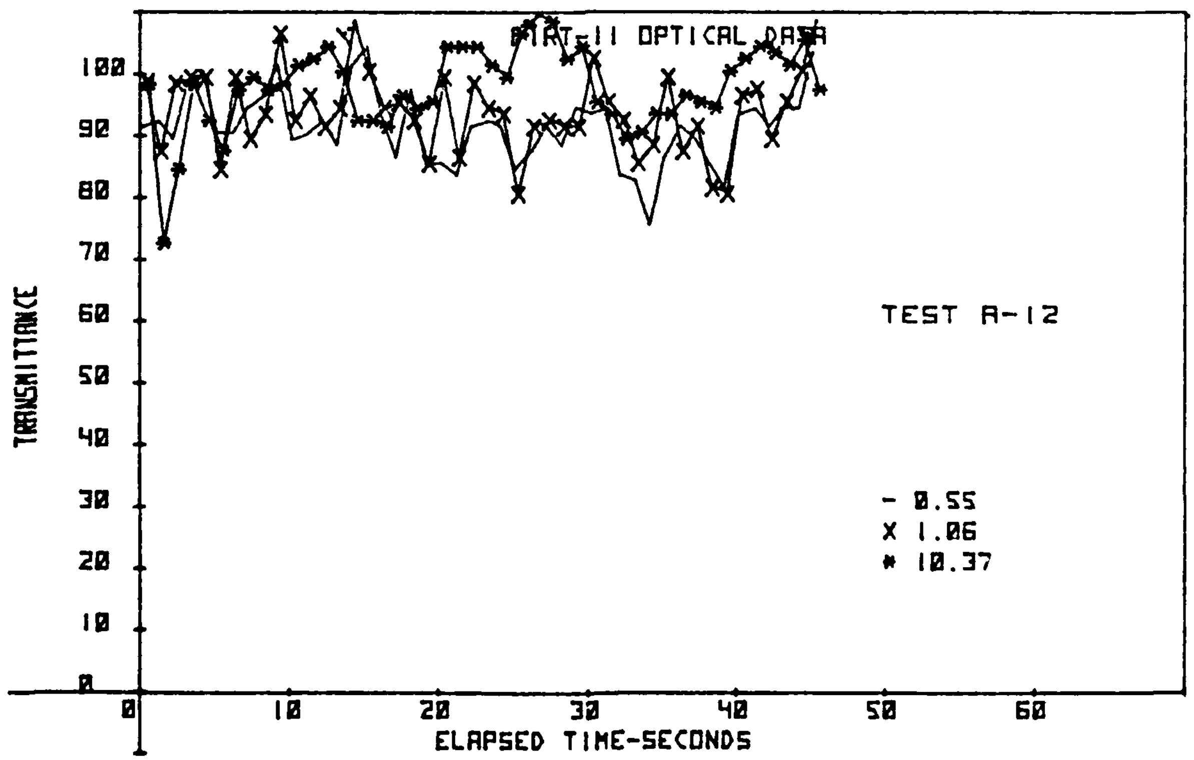

Fig. 38 — 155 mm static, 7-19-79, 1817, dry soil

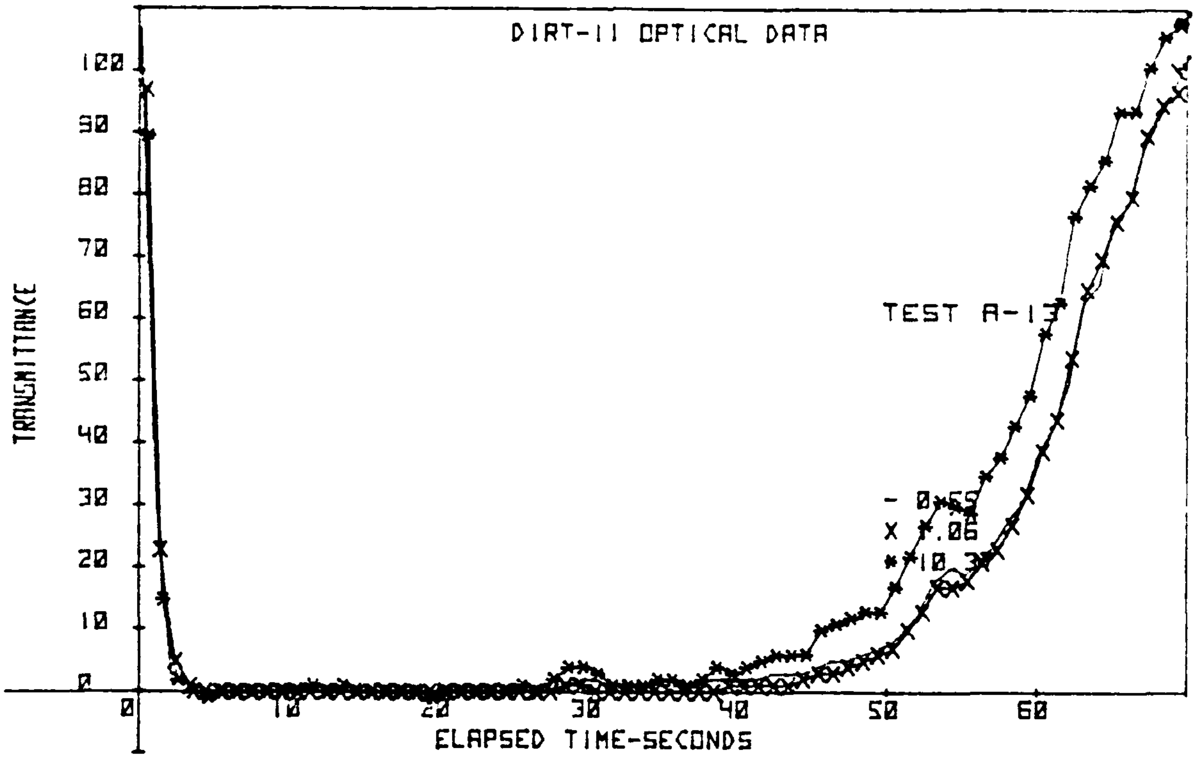

Fig. 39 — 155 mm static, 7-19-79, 1534, dry soil

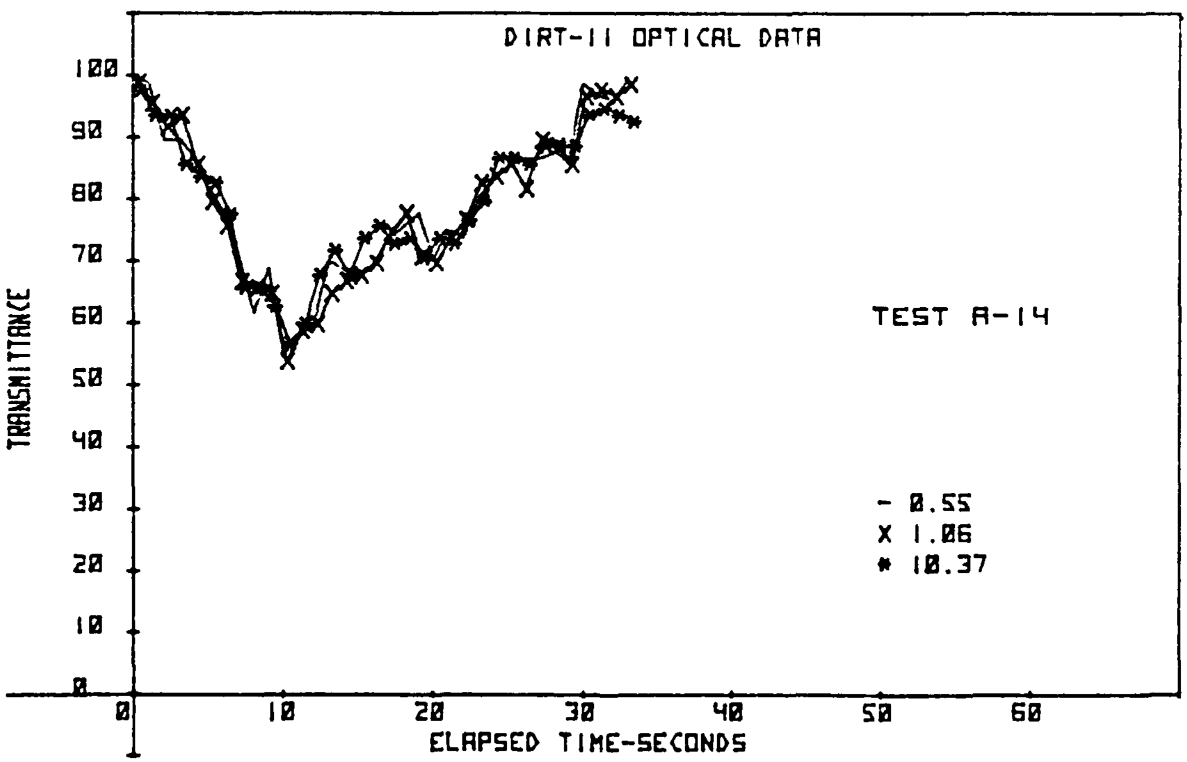

Fig. 40 — 155 mm static, 7-19-79, 1655, dry soil

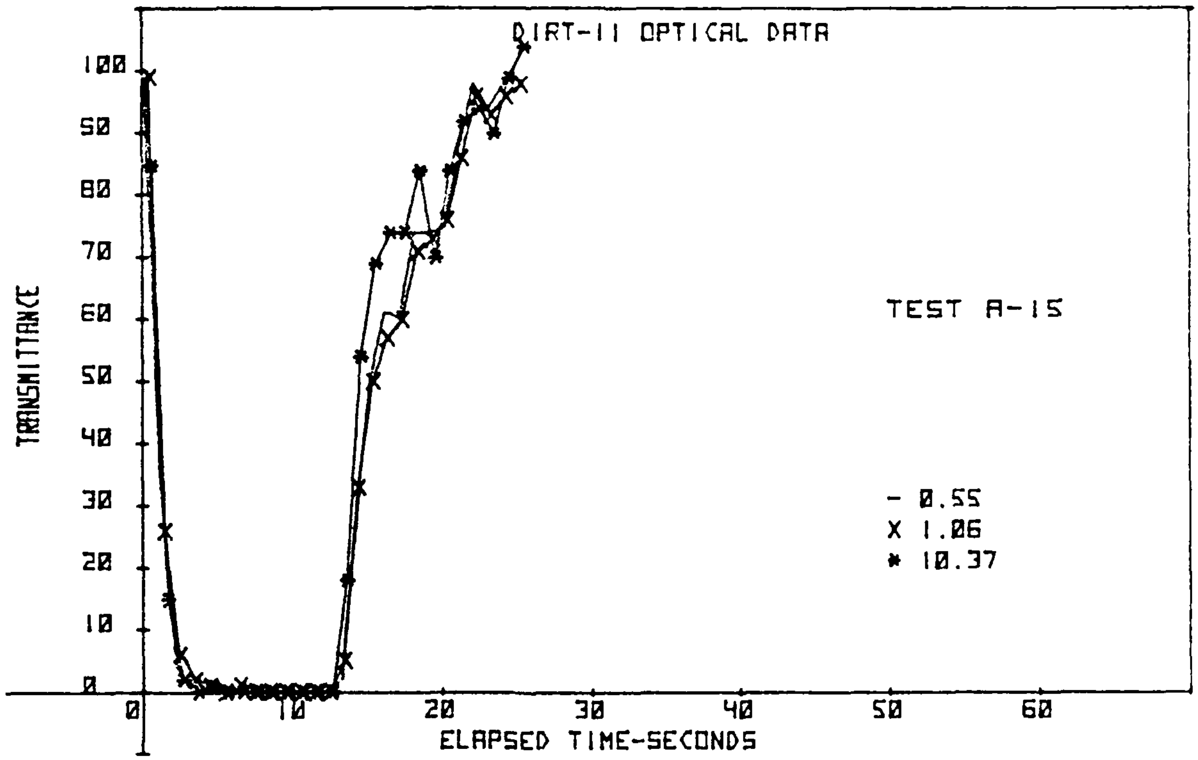

Fig. 41 — 155 *mm static*, 7-19-79, 1734, dry soil

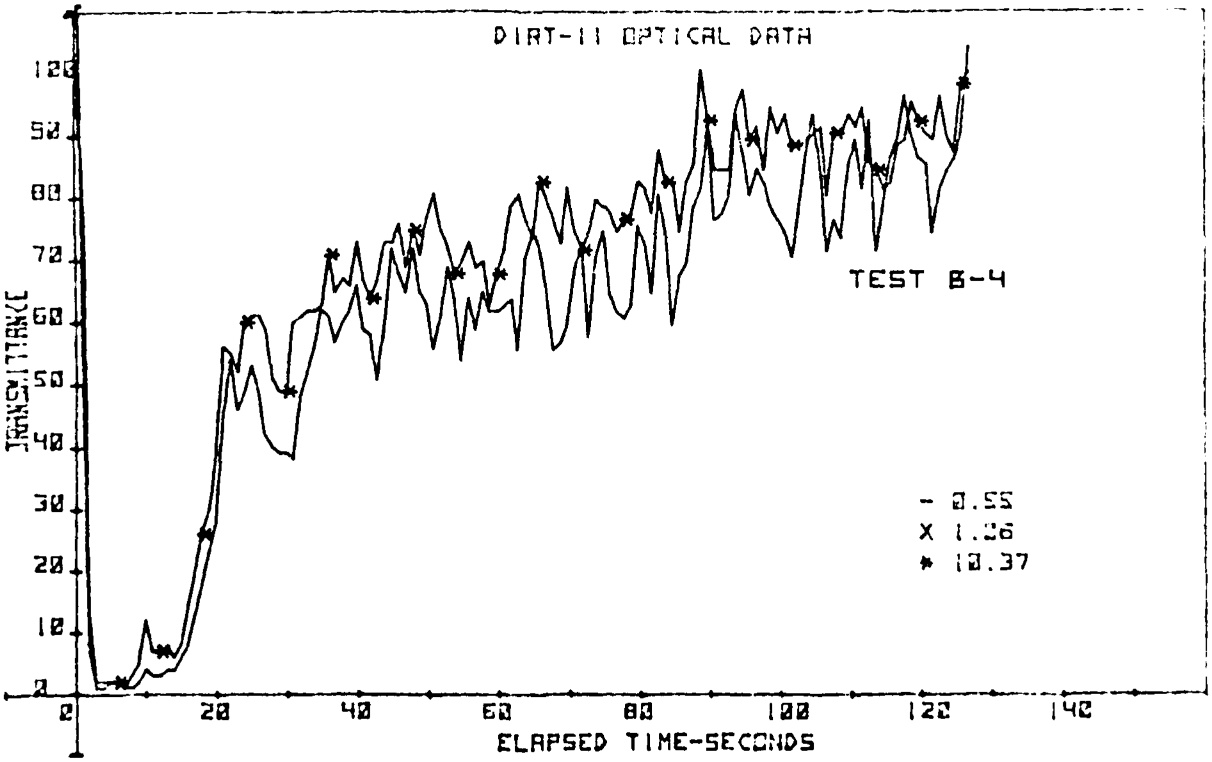

Fig. 42 — 105 mm static, 7-25-79, 1701, dry soil

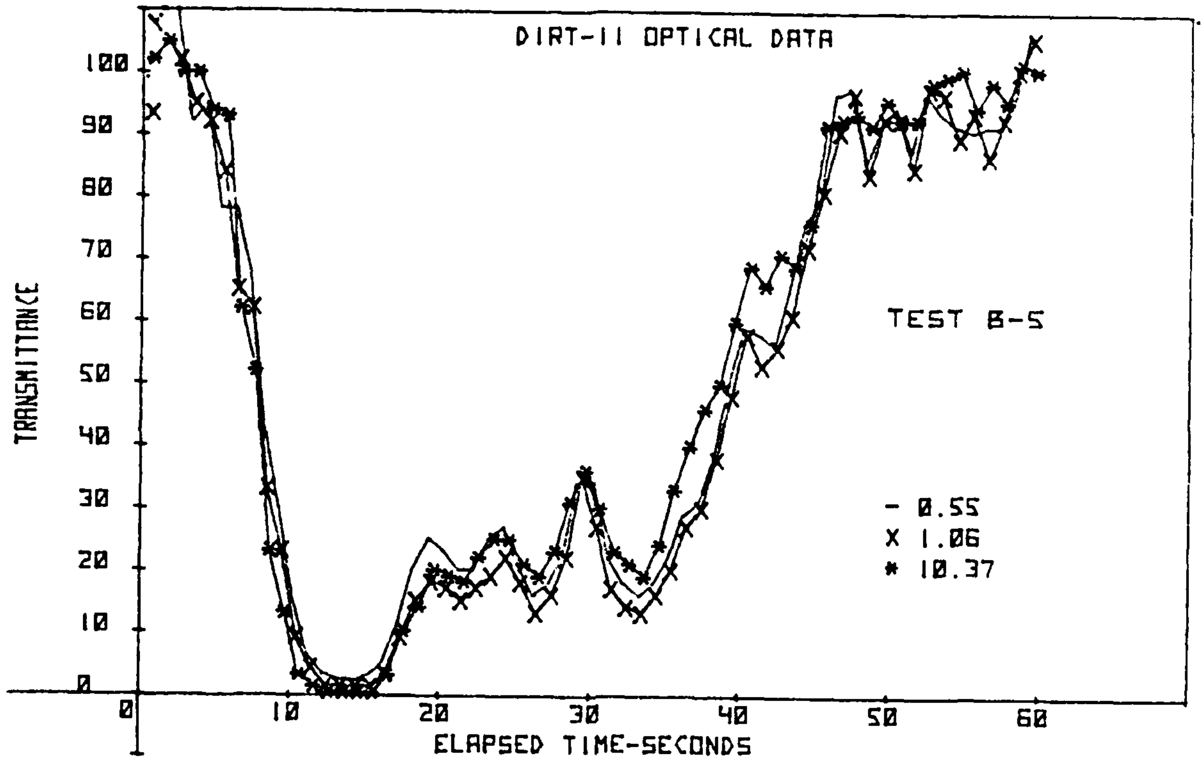

Fig. 43 — 105 mm static, 7-23-79, 1631, dry soil

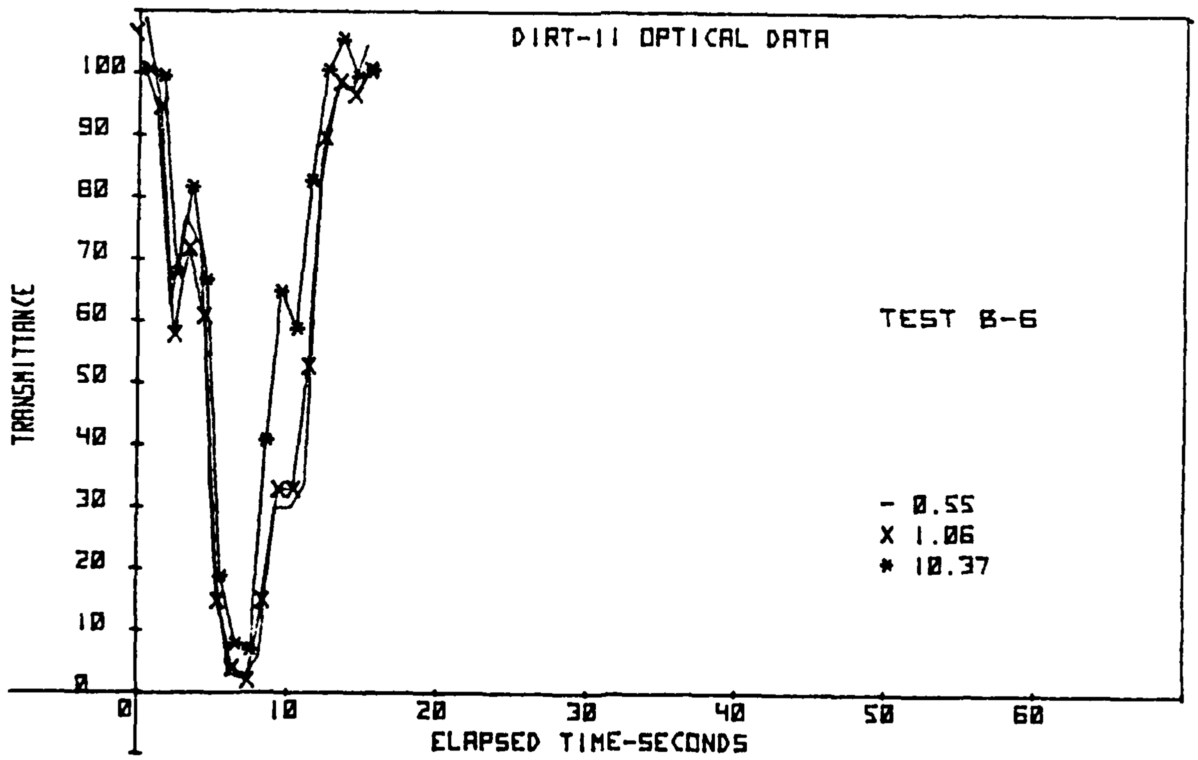

Fig. 44 — 105 mm static, 7-23-79, 1512, dry soil

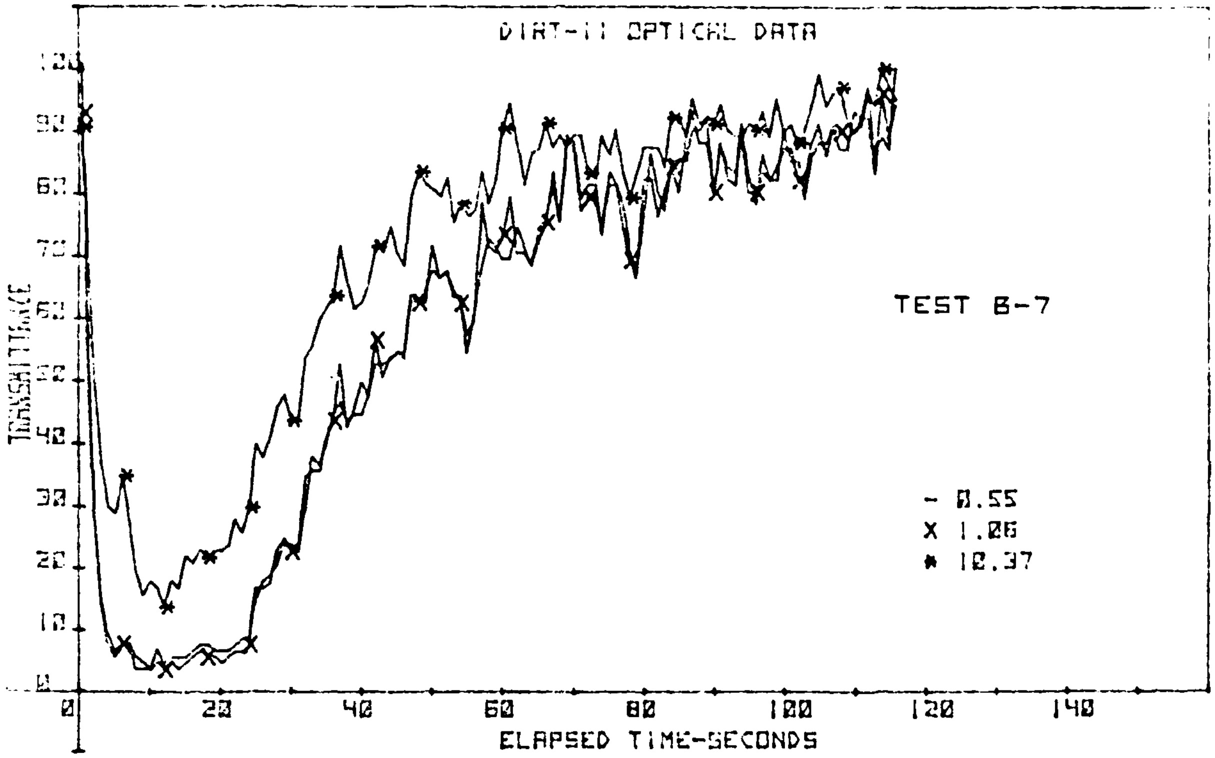

Fig. 45 — 105 mm static, 7-23-79, 1540, dry soil

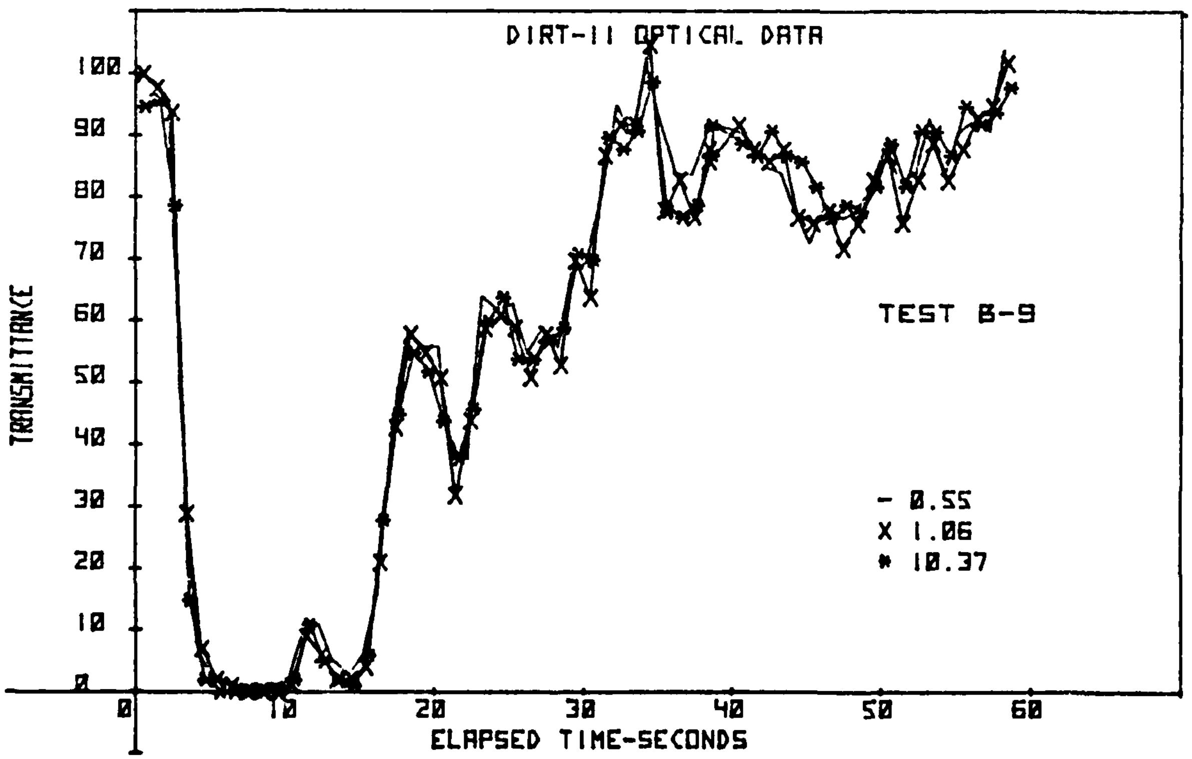

Fig. 46 — 105 mm static, 7-24-79, 1616, dry soil

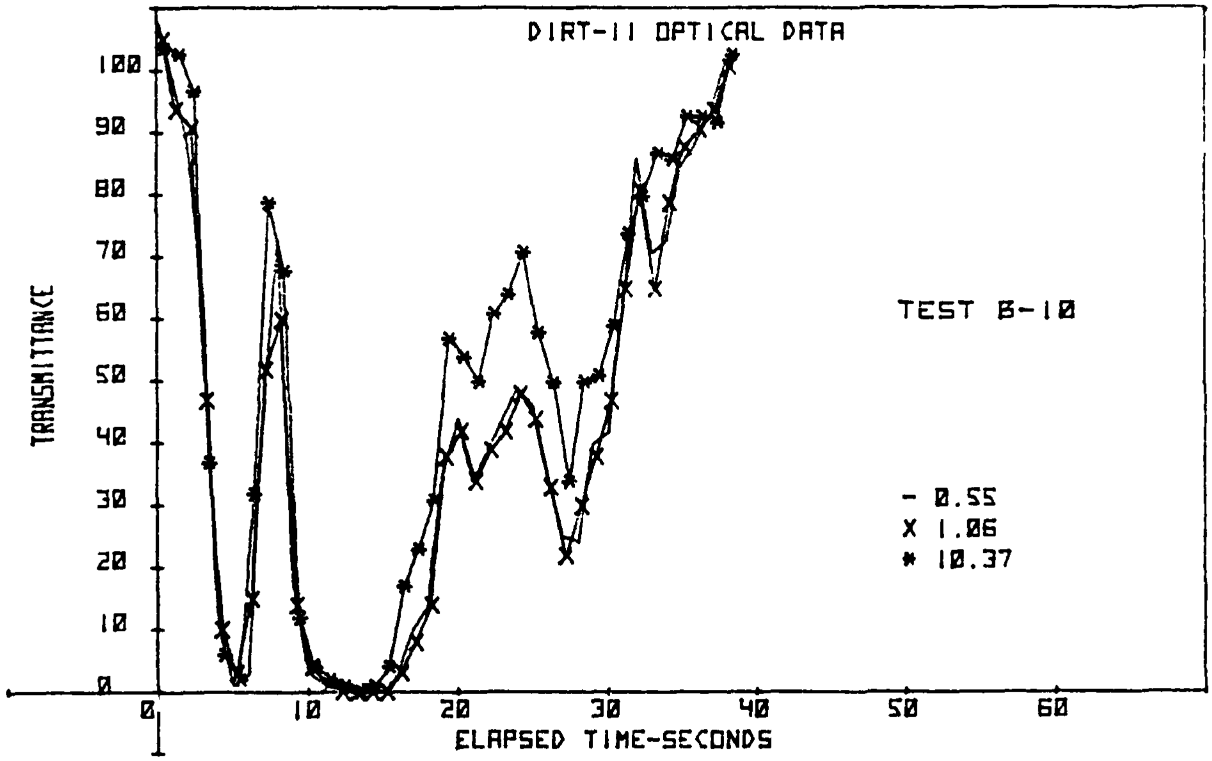

Fig. 47 — 105 mm static, 7-24-79, dry soil

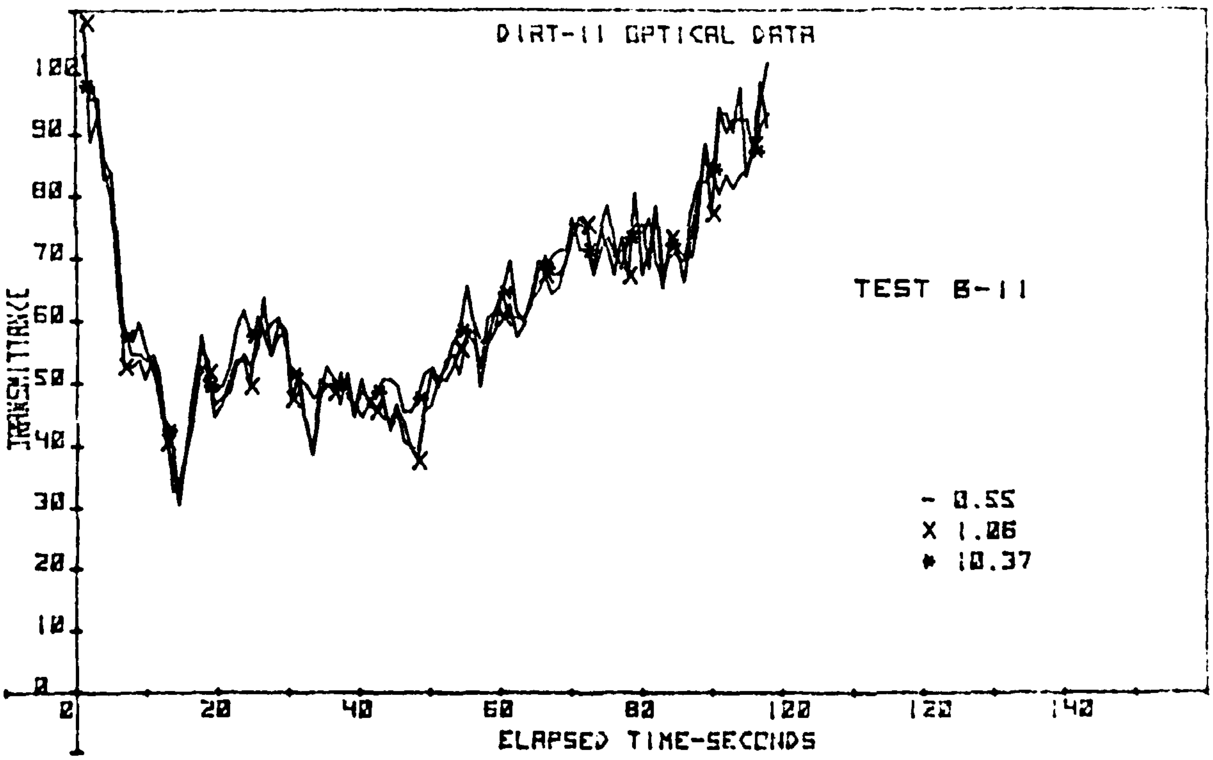

Fig. 48 — 105 mm static, 7-24-79, 1548, dry soil

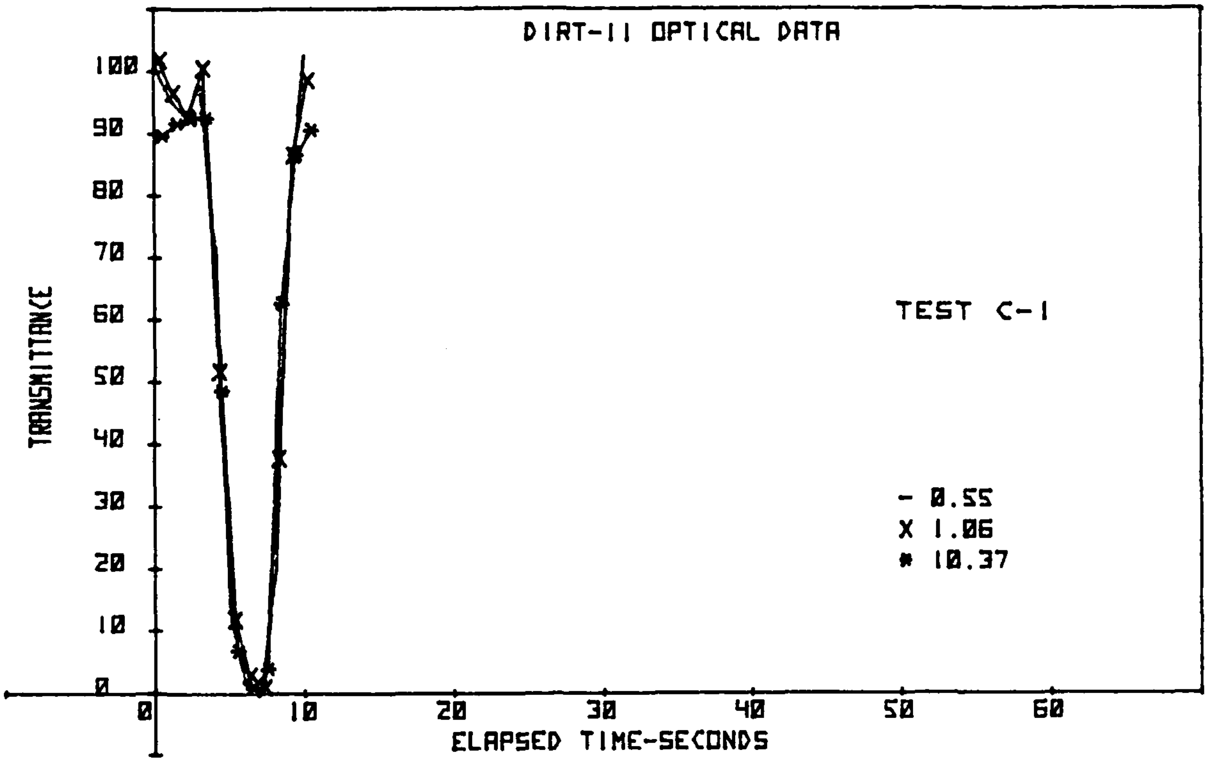

Fig. 49 — 4.2 inch mortar, 7-27-79, 1546, wet soil

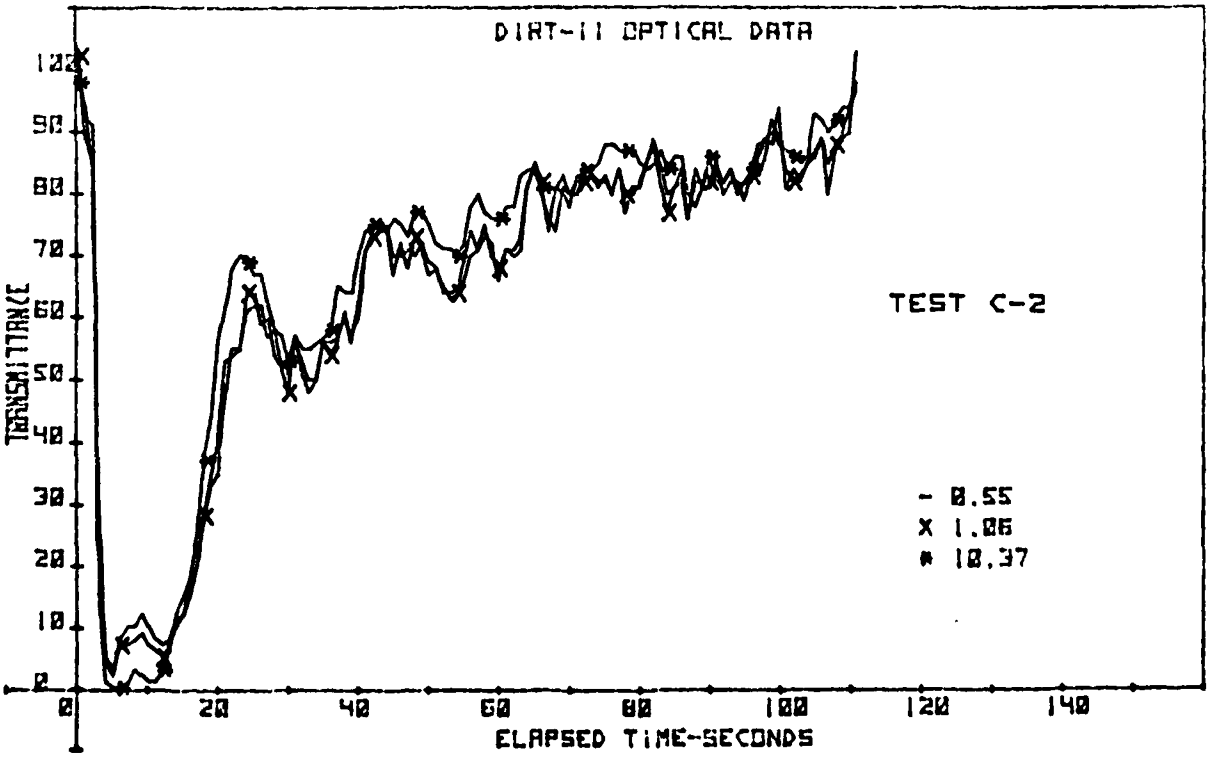

Fig. 50 — 4.2 inch mortar, 7-27-79, 1510, wet soil

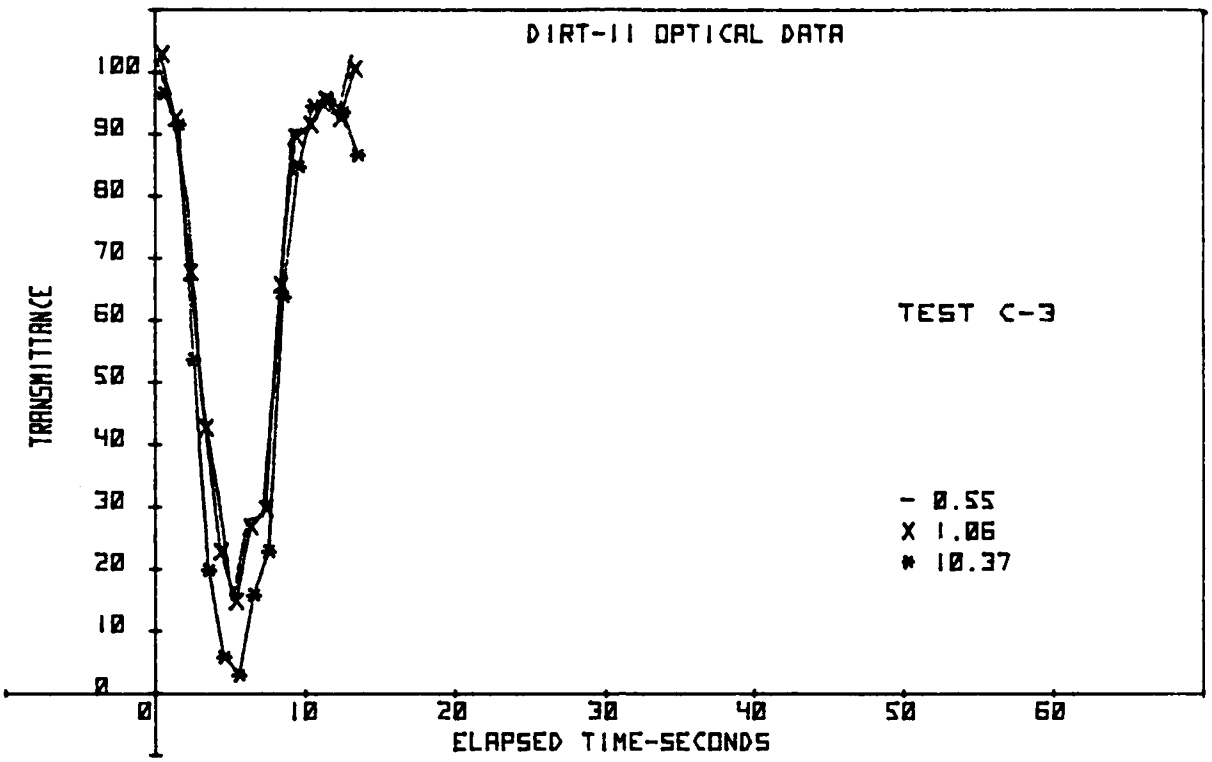

Fig. 51 — 4.2 inch mortar, 7-26-79, 1725, wet soil

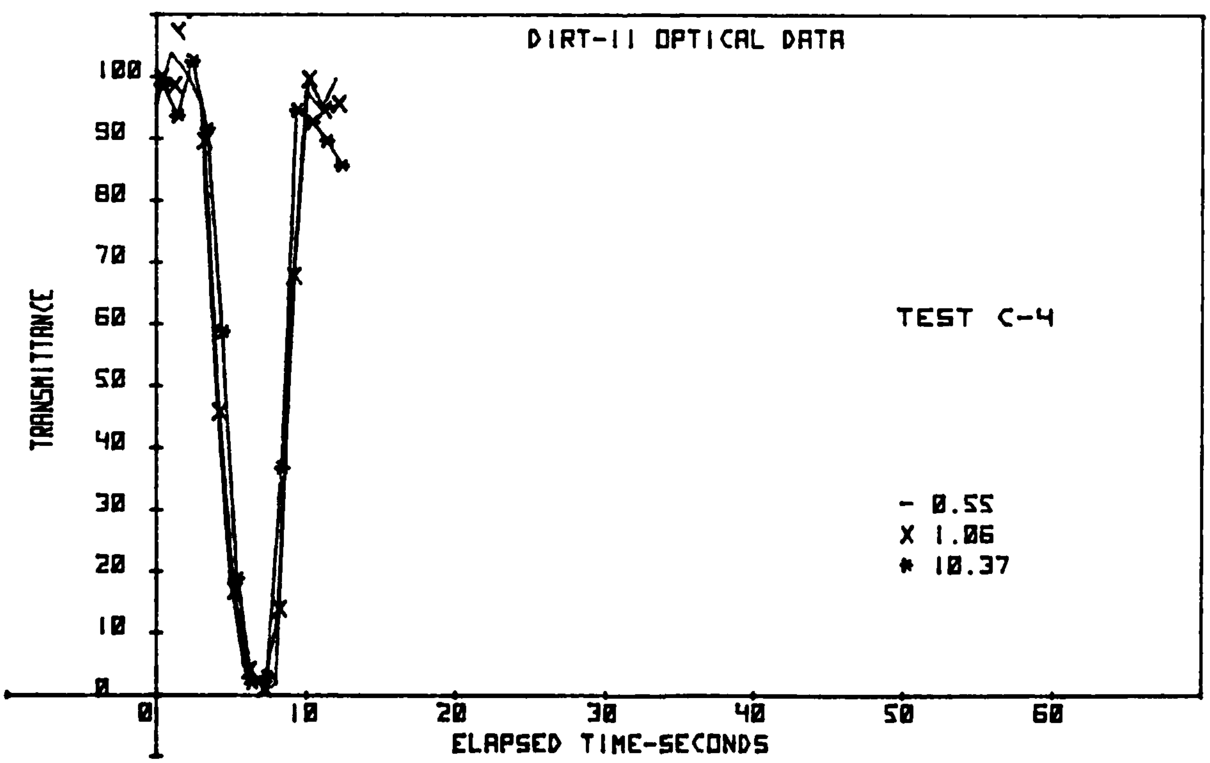

Fig. 52 — 4.2 inch mortar, 7-26-79, 1725, wet soil

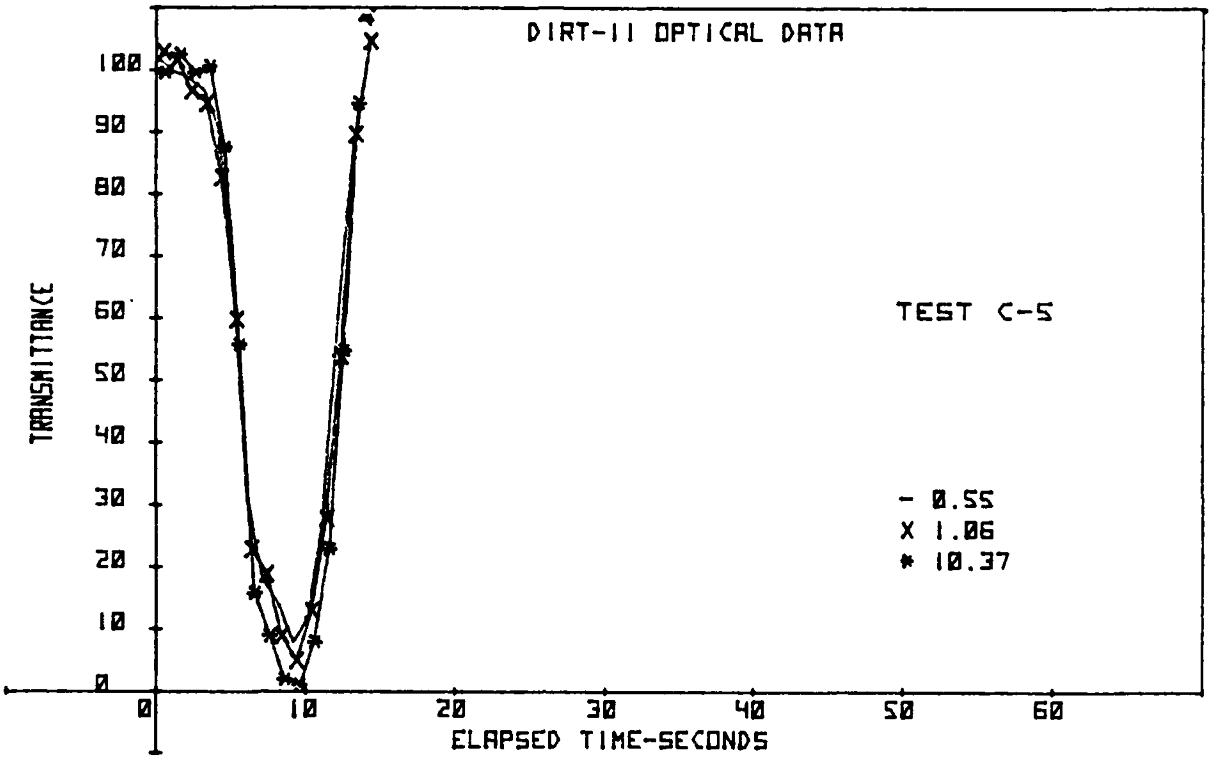

Fig. 53 — 4.2 inch mortar, 7-26-79, 1655, wet soil

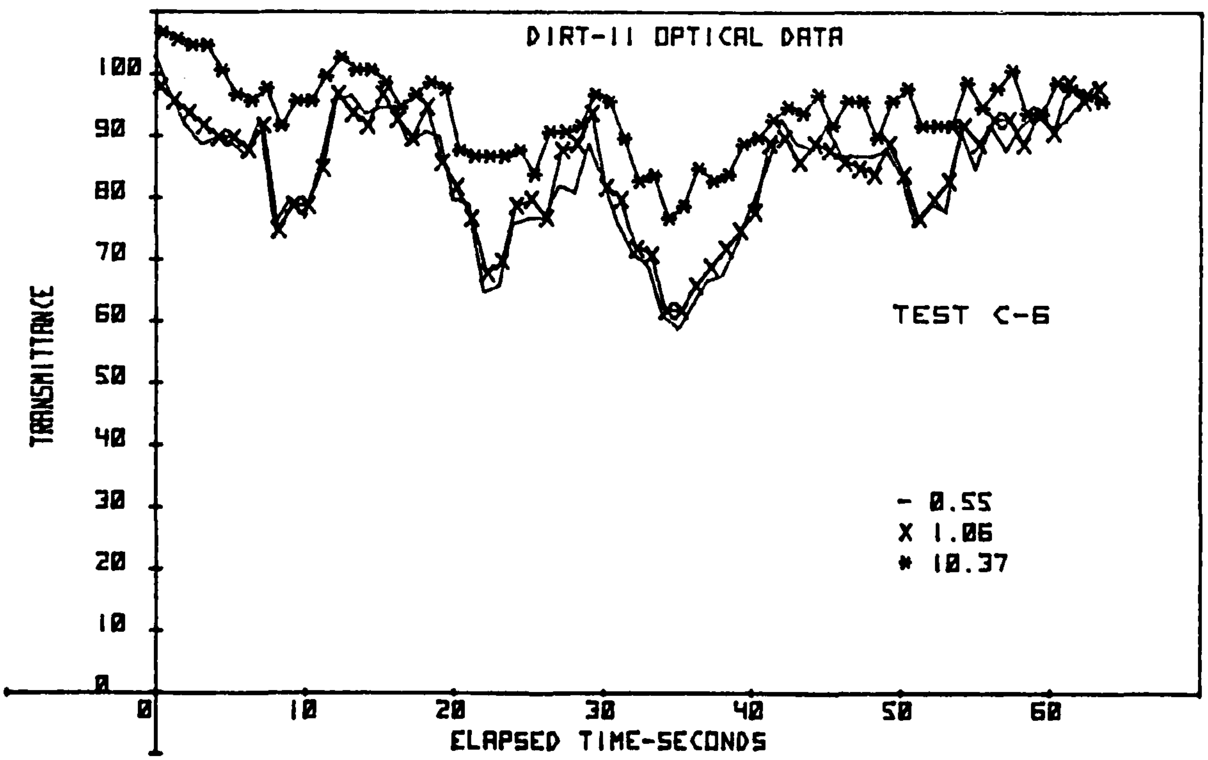

Fig. 54 — 4.2 inch mortar, 7-26-79, 1625, wet soil

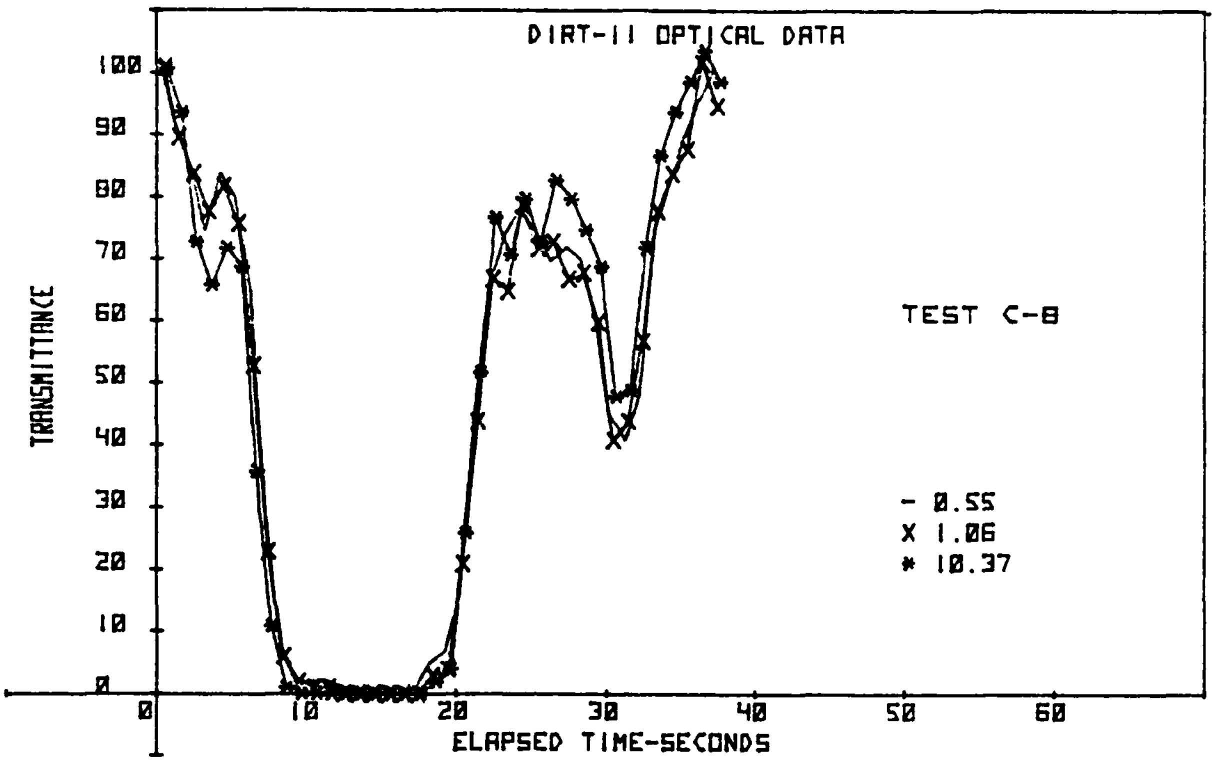

Fig. 55 — 4.2 inch mortar, 7-27-79, 1616, wet soil

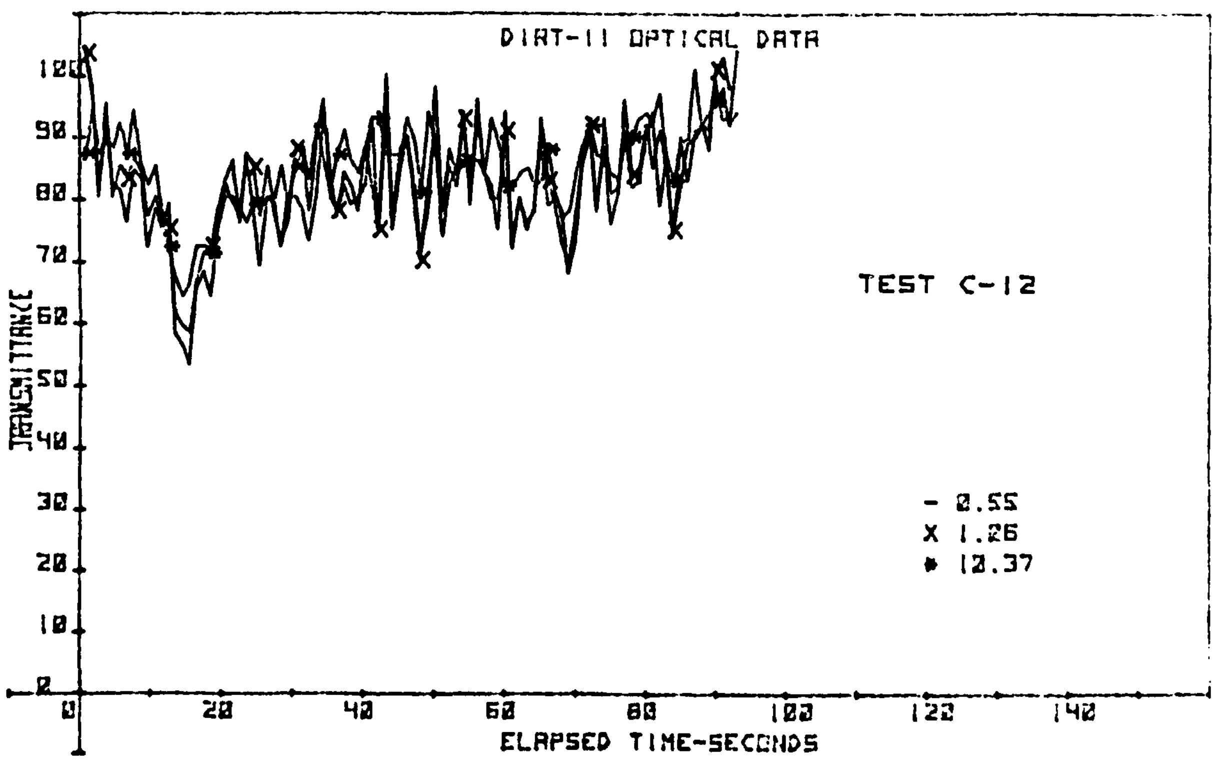

Fig. 56 — Comp 4, 7-28-79, 1749, dry soil

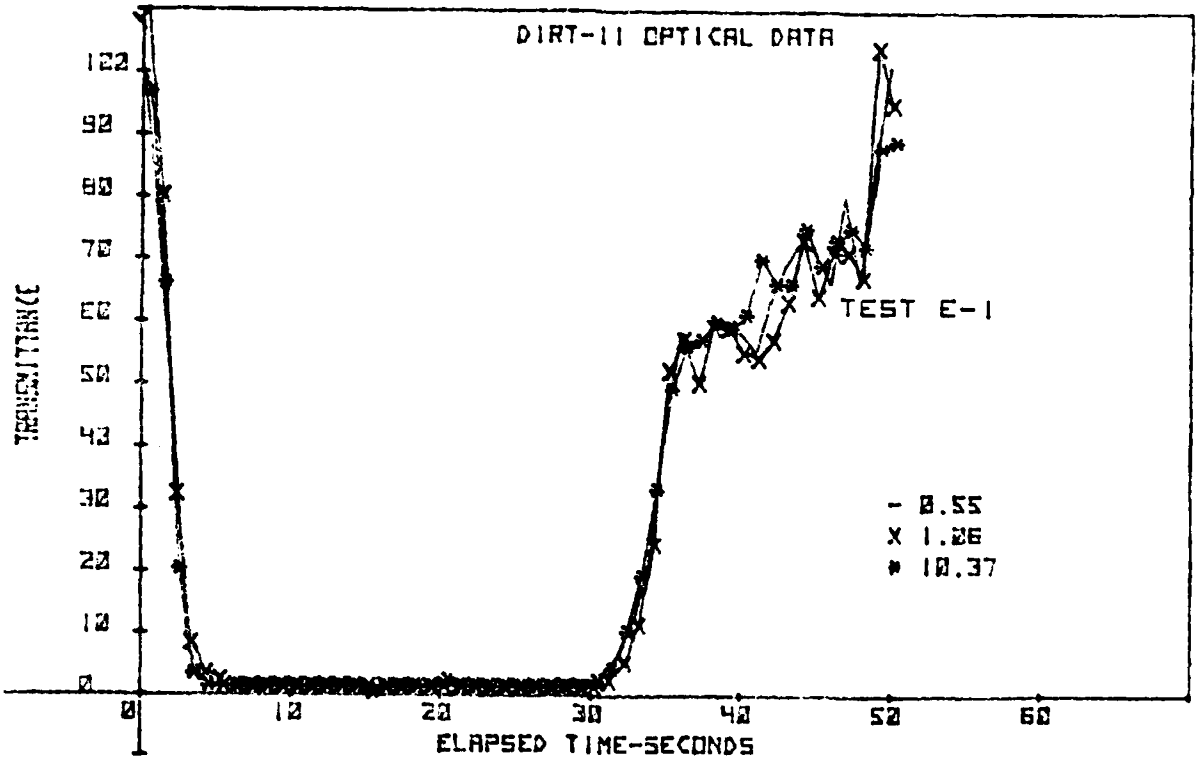

Fig. 57 — Comp 4, 7-23-79, 1713, dry soil

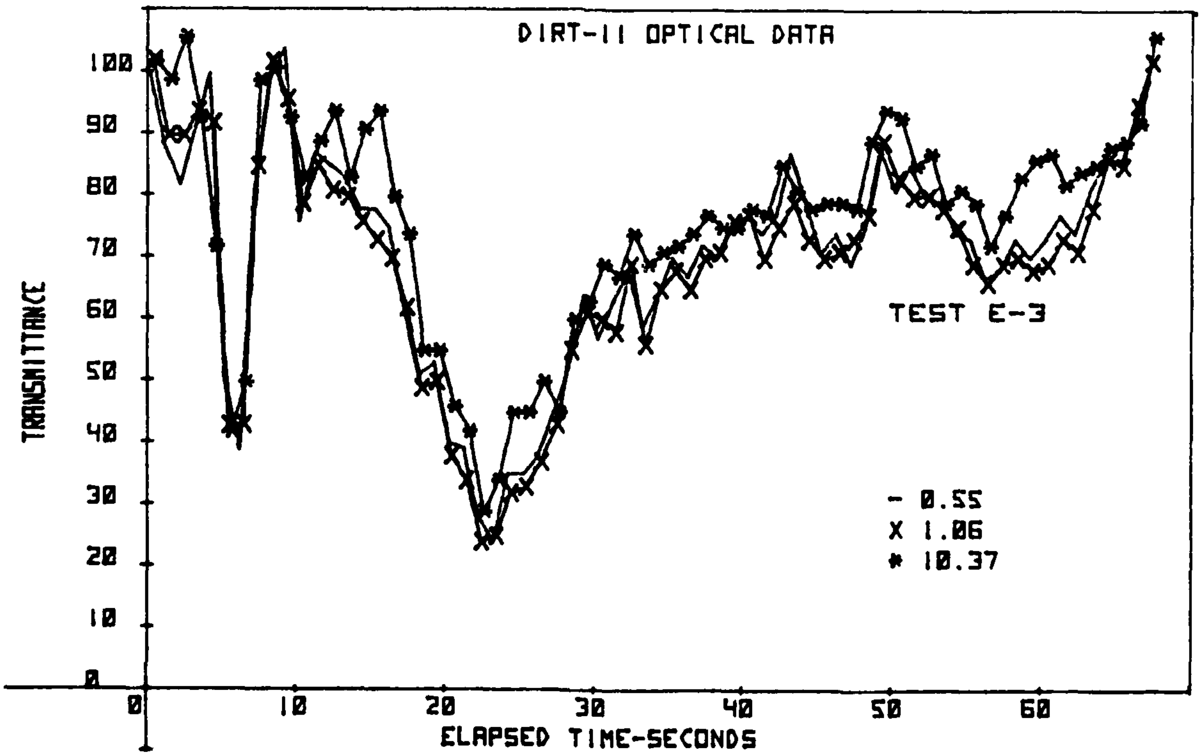

Fig. 58 — Comp 4, 7-25-79, 1734, dry soil

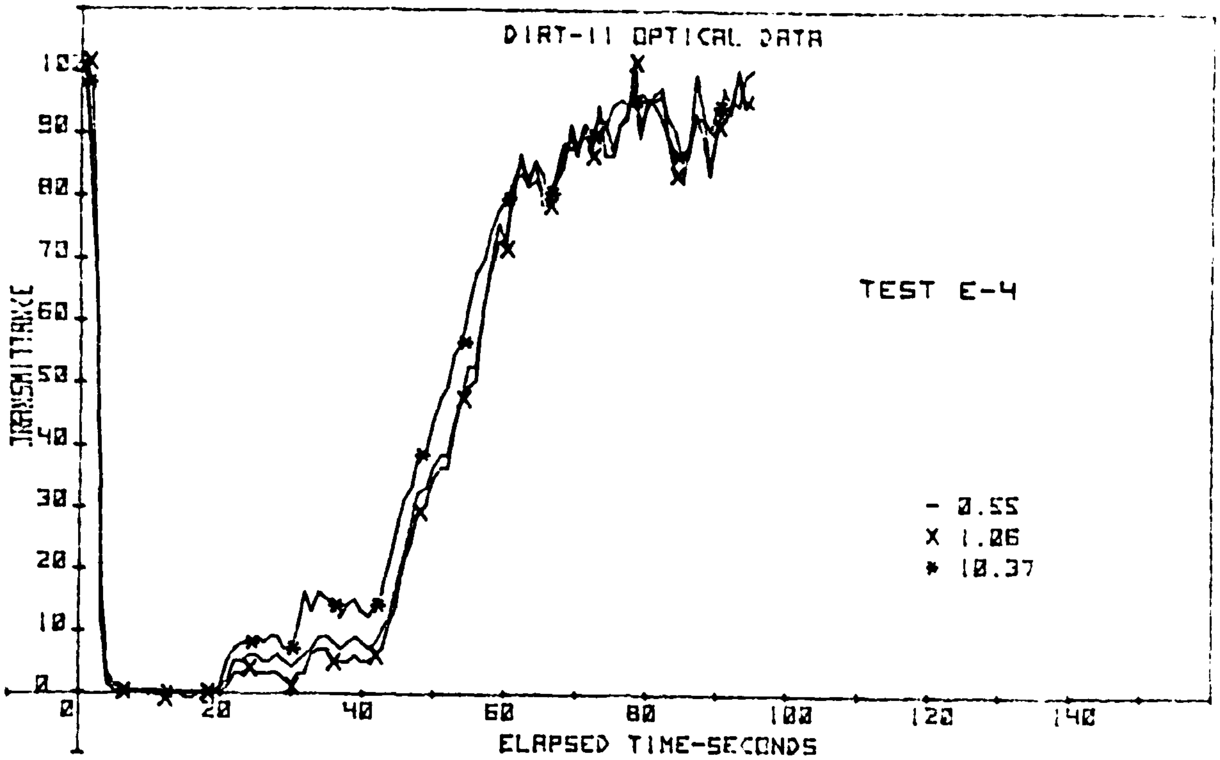

Fig. 59 — Comp 4, 7-25-79, 1509, dry soil

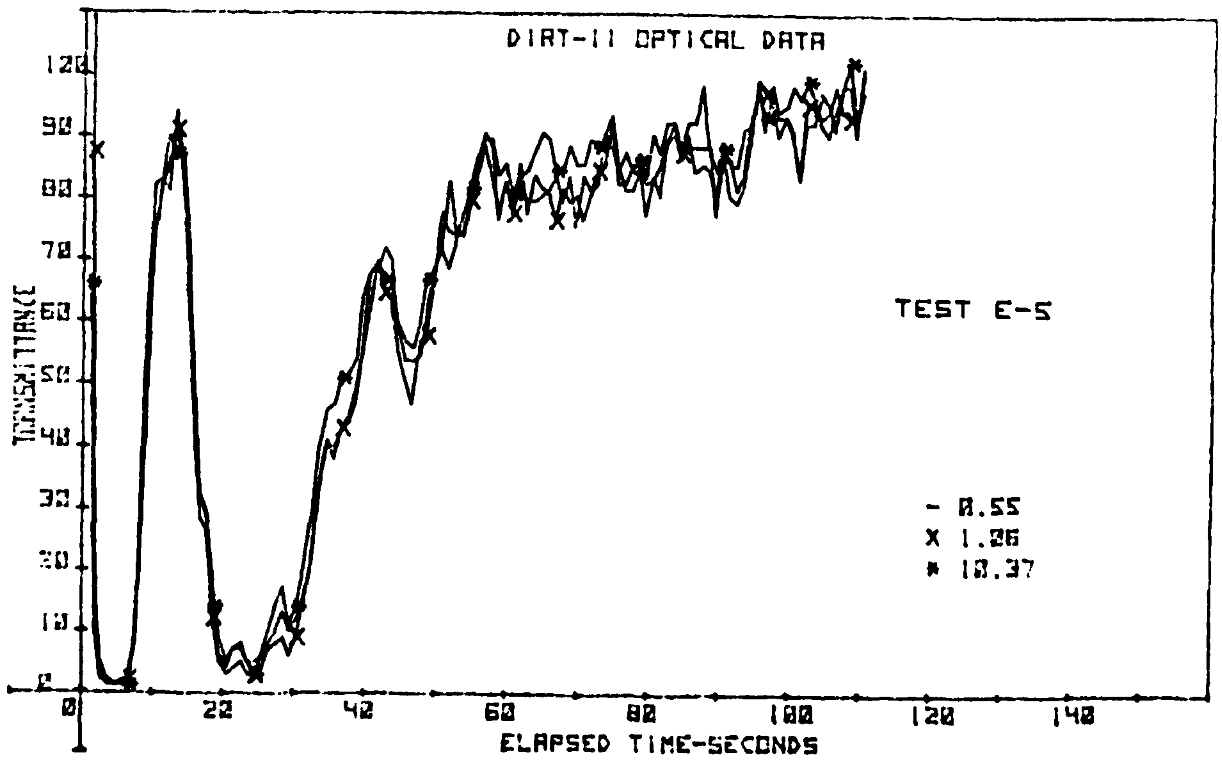

Fig. 60 — Comp 4, 7-25-79, 1541, dry soil

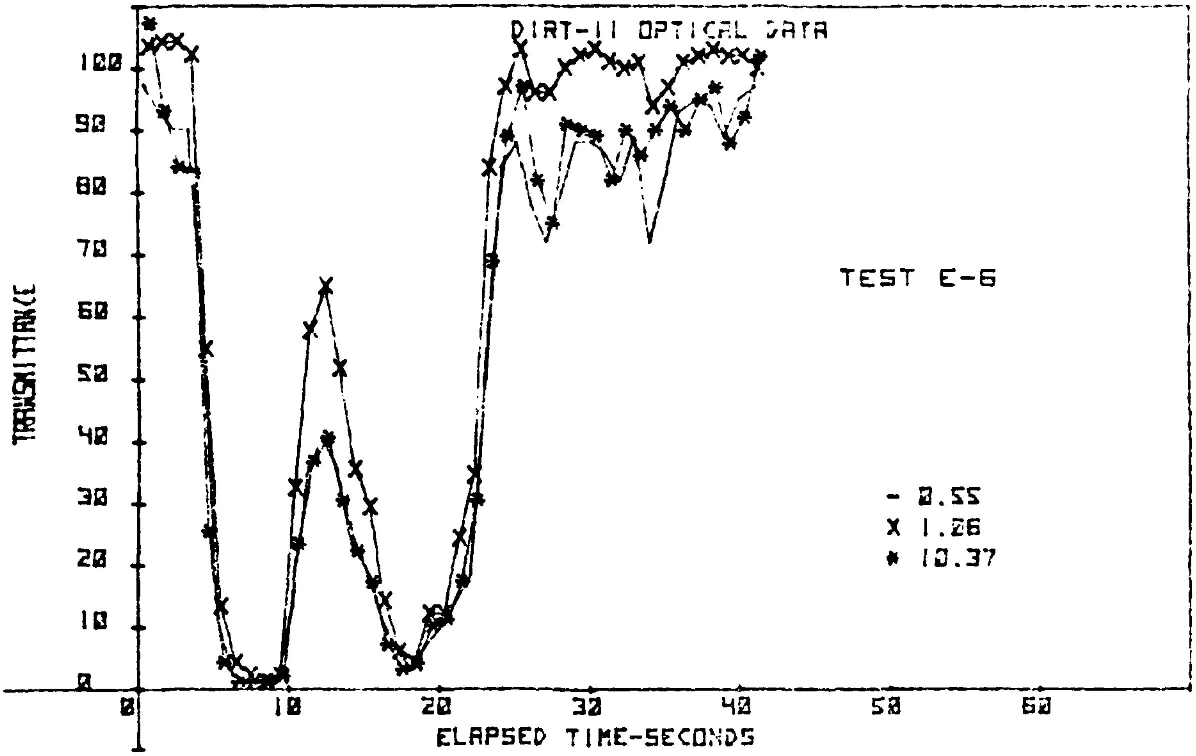

Fig. 61 — Comp 4, 7-25-79, 1809, dry soil

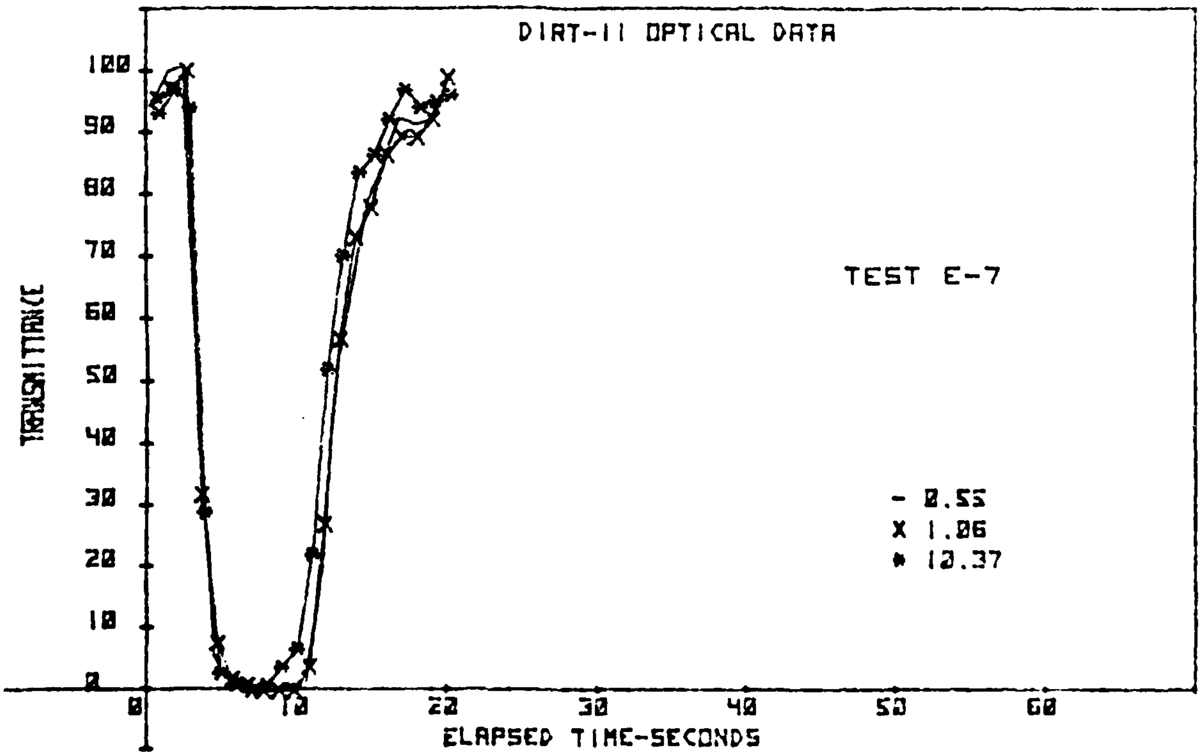

Fig. 62 — Comp 4, 7-25-79, 1511, wet soil

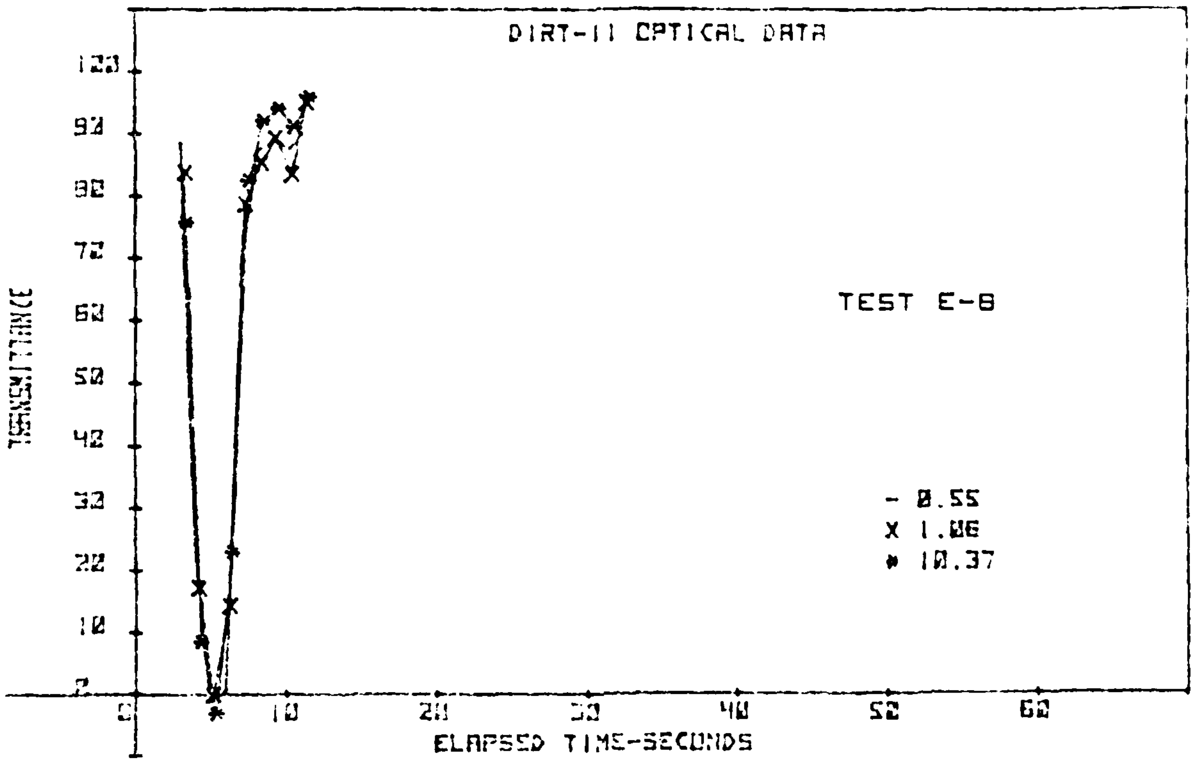

Fig. 63 — Comp 4, 7-26-79, 1552, wet soil

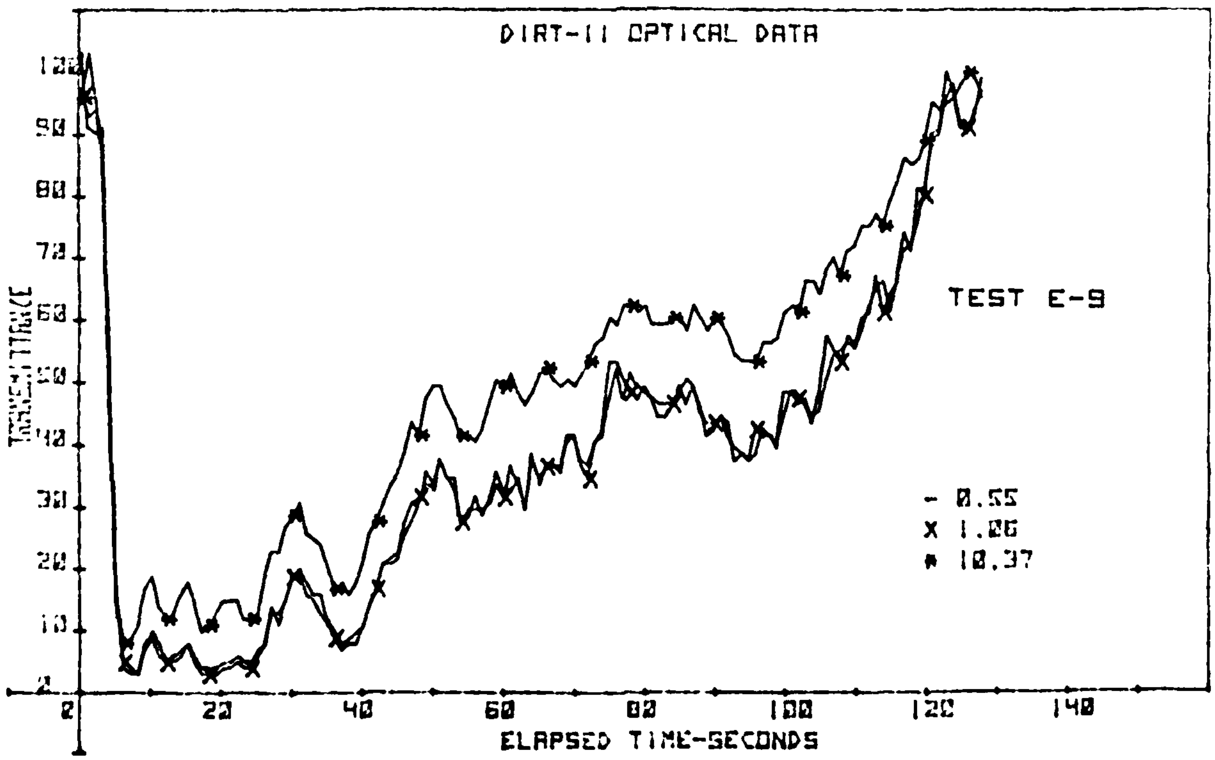

Fig. 64 — Comp 4, 7-28-79, 1602, dry soil

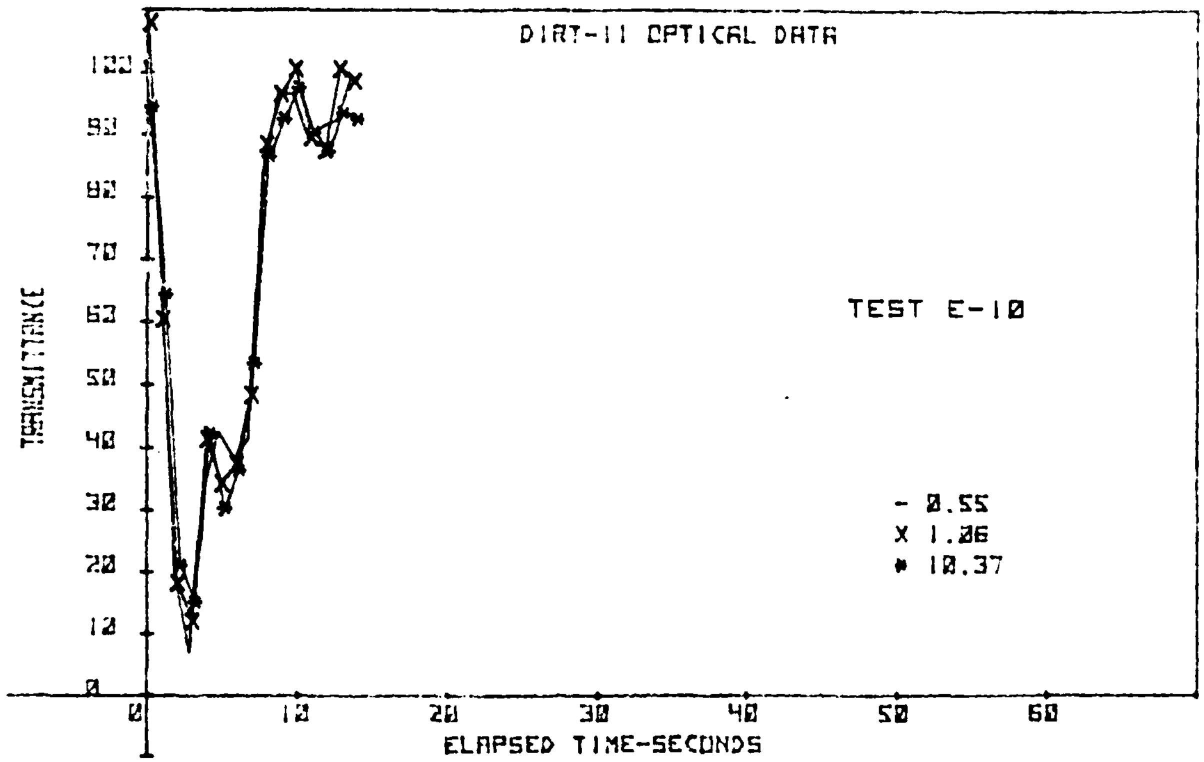

Fig. 65 — Comp 4, 7-28-79, 1633, dry soil

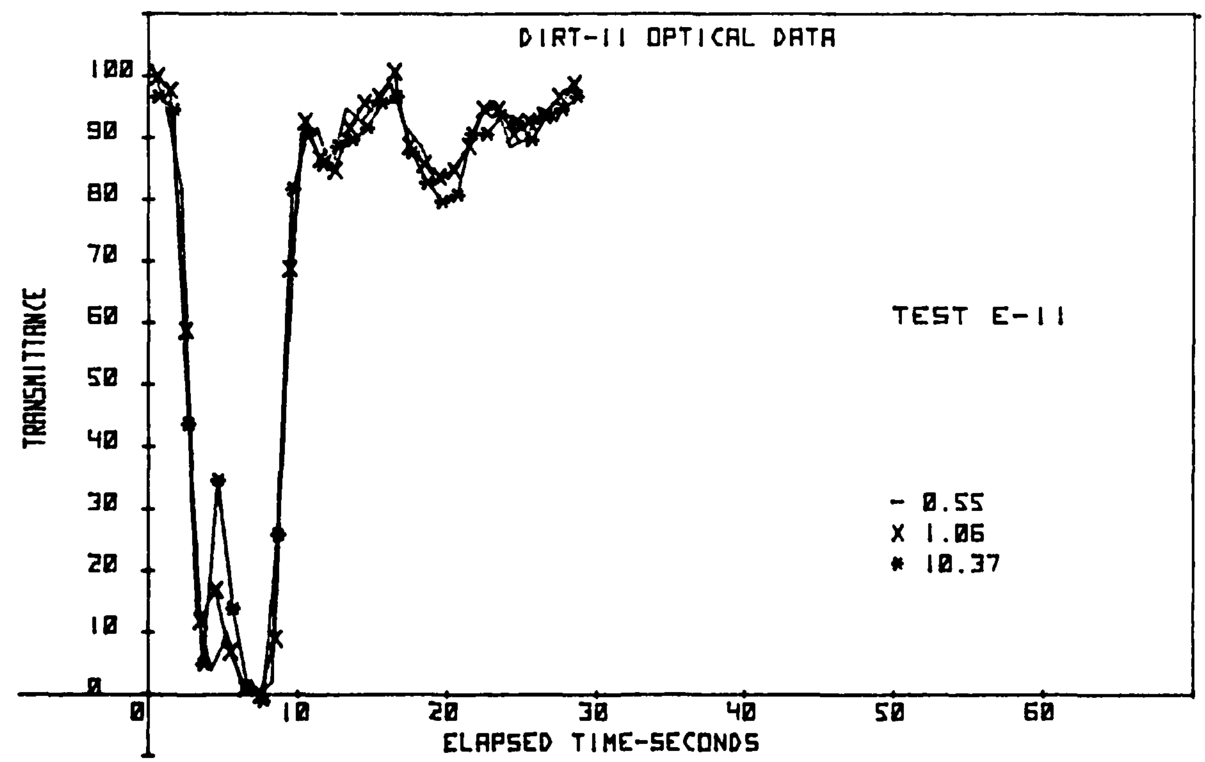

Fig. 66 — Comp 4, 7-28-79, 1532, dry soil

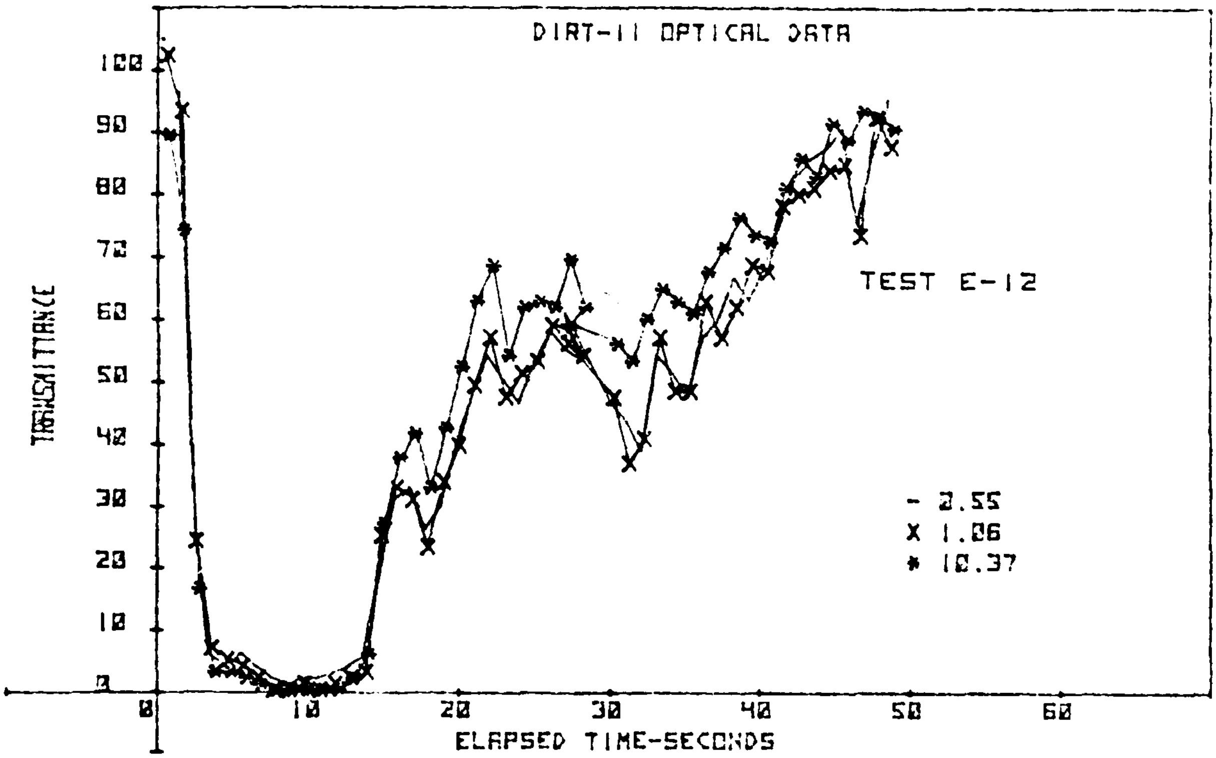

Fig. 67 — Comp 4, 7-28-79, 1716, dry soil

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